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*SYMINGTON, W. N.,	P. O. Box 2011, New York City.
*SYMONS, W. R.,	Pottsville, Pa.
*TASKER, CHARLES P.,	Morris, Tasker & Co., Limited, Philadelphia.
*TAYLOR, CHARLES L.,	Pittsburgh Bessemer Steel Co., Limited, Pittsburgh, Pa.
*TAYLOR, FRED. W.,	Pueblo, Colorado.
†TAYLOR, P. A.,	Pottsville, Pa.
*TAYLOR, PERCYVALE,	6 Queen Street Place, London, E. C., England.
*TAYLOR, W. J.,	Chester, Morris Co., N. J.
*TEFFT, WALTER,	Mineville, Essex Co., N. Y.
*TEMPLE, JOHN C.,	Globe Iron Works, Dayton, Ohio.
†THACHER, ARTHUR,	108 E. Thirty-sixth Street, New York City.
*THACKRAY, GEORGE E.,	P. O. Box 789, New York City.
*THAW, WILLIAM, JR.,	Pittsburgh, Pa.
*THIES, A.,	Concord, N. C.
*THOMAS, ALEXANDER,	Bolton Steel Co., Canton, Ohio.
*THOMAS, D. H.,	Alburtis, Pa.
*THOMAS, EDWIN,	Catasauqua, Pa.
*THOMAS, JOHN,	Hokendauqua, Pa.
*THOMAS, SAMUEL,	Catasauqua, Pa.
*THOMAS, SIDNEY G.,	9 Palace Chambers, Bridge Street, Westminster, London, S. W., England.
*THOMÉ, SAMUEL W.,	379 Fulton Street, Brooklyn, N. Y.
*THOMLINSON, WILLIAM,	West Hartlepool, England.
*THOMPSON, PROF. C. O.,	Terre Haute, Indiana.
*THOMPSON, E. RAY,	Troy, N. Y.
†THOMPSON, GEORGE S.,	Troy, N. Y.
*THOMPSON, HEBER S.,	Pottsville, Pa.
*THOMPSON, ROBERT M.,	292 Pearl Street, New York City.
*THOMSON, JOHN L.,	Bergen Point, N. J.
*THONARD, LÉON,	Sofia, Bulgaria.
*THURSTON, PROF. R. H.,	Stevens Institute of Technology, Hoboken, N. J.
*TIERNEY, JOHN J.,	Tremont, Pa.
*TILEMANN, J. N.,	Argentine, Kansas.
*TODD, JAMES,	127 North Avenue, Allegheny City, Pa.
*TORRANCE, H. C.,	Lucy Furnace Co., Pittsburgh, Pa.
*TORRANCE, J. FRASER,	Buckingham, P. Quebec, Canada.
*TORREY, HERBERT G.,	U. S. Assay Office, New York City.
*TORRY, DOLPHUS,	201 Seventh Avenue, New York City.
*TOUCEY, DONALD B.,	57 W. Fifty-third Street, New York City.
*TOWER, A.,	Poughkeepsie, N. Y.
*TOWNE, LINWOOD O.,	Rico, Dolores Co., Colorado.
*TOWNSEND, DAVID,	1723 Wallace Street, Philadelphia.
*TOWNSEND, HENRY T.,	218 S. Fourth Street, Philadelphia.
*TRABER, JACOB,	2 Public Landing, Cincinnati, Ohio.

*Trent, L. C., ... 423 Blake Street, Denver, Colorado.
*Trippel, Alexander, ... 181 Broadway, New York City.
*Troilius, Magnus, ... Midvale Steel Works, Nicetown, Philadelphia.
*Trowbridge, Prof. William P., . . . School of Mines, New York City.
*Tucker, Alfred, ... 220 Walnut Street, Philadelphia.
†Tuttle, H. A., ... Cleveland, Ohio.
*Tyler, Alfred L., ... Woodstock Iron Co., Anniston, Ala.

*Valentine, M. D., ... Woodbridge, N. J.
*Van Arsdale, W. H., ... Aurora, Ill.
*Van Blarcom, E. C., ... P. O. Box 2085, San Francisco, Cal.
*Van Diest, P. H., ... 679 California Street, Denver, Colorado.
*Vandling, A. H., ... Scranton, Pa.
*Van Lennep, D., . . . Granite Basin, via Buck's Ranch, Plumas Co., Cal.
*Van Tassel, Howard A., ... Houghton, Mich.
*Van Voorhis, W. W., ... Manhattanville, New York City.
*Vannier, Charles H., ... Succasunna, Morris Co., N. J.
*Veeder, Herman, ... Eddyville, Iowa.
*Vezin, Henry A., ... P. O. Box 144, Leadville, Colorado.
*Vivian, George G., ... Freeland, Clear Creek Co., Colorado.
*Vulté, Hermann T., ... 223 W. Forty-third Street, New York City.

*Wait, Prof. Charles E., ... Rolla, Phelps Co., Missouri.
*Waite, George R., ... 119 S. Fourth Street, Philadelphia.
*Walker, J. C., ... 238 Bissell Street, Chicago, Ill.
†Walker, John A., ... P. O. Box 21, Jersey City, N. J.
†Walker, N. B., ... 235 Water Street, New York City.
*Walker, W. R., ... Crown Point, N. Y.
*Waller, Dr. Elwyn, ... School of Mines, New York City.
*Walsh, Edward, Jr., ... 2721 Pine Street, St. Louis, Mo.
*Ward, Willard P., ... 80 Madison Avenue, New York City.
†Warner, L. E., ... Johnston Buildings, Cincinnati, Ohio.
*Warner, Willard, ... Tecumseh, Cherokee Co., Alabama.
*Warren, G. Harry, ... 520 Fifth Avenue, New York City.
*Warren, Walter P., ... Troy, N. Y.
*Wartenweiler, Alfred, ... Butte City, Montana.
*Waterman, H. L., . . . Care of C. H. Odell, 47 Wall Street, New York City.
*Waters, J. H. E., ... Silverton, Colorado.
†Watt, Arthur K., ... 709 President Street, Brooklyn, N. Y.
*Watts, David, ... 223 Market Street, Harrisburg, Pa.
†Watts, Ethelbert, ... 326 Walnut Street, Philadelphia.
*Weaver, V. W., ... Coplay, Lehigh Co., Pa.
*Webb, H. Walter, ... 37 Wall Street, New York City.
*Weeks, Joseph D., ... P. O. Box 1547, Pittsburgh, Pa.
*Weimer, P. L., ... Lebanon, Pa.
*Weir, Charles G., ... Cheyenne, Wyoming.
*Wellman, S. T., ... Otis Iron and Steel Co., Cleveland, Ohio.
*Wells, Bard, ... Pottsville, Pa.
†Wells, Calvin, ... A. French & Co., Pittsburgh, Pa.
*Wells, H. L., ... South Pueblo, Colorado.
*Wendt, Arthur F., ... 414 E. Fifty-first Street, New York City.

*Wentz, J. S., ... Mauch Chunk, Pa.
*Werner, Augustin, ... Mapimi, Durango, Mexico.
*West, A. G., ... Cedartown, Polk Co., Ga.
*Westbrook, C. S., ... Spragueville, St. Lawrence Co., N. Y.
*Westbrook, Charles R., ... Ogdensburgh, St. Lawrence Co., N. Y.
*Wheeler, H. A., ... Washington University, St. Louis, Mo.
*Wheeler, Moses D., . . . P. O. Box 231, Stapleton, Staten Island, N. Y.
*Wheeler, William D., ... U. S. Assay Office, Helena, Montana.
*Wheelock, Jerome, ... Worcester, Mass.
*Whinery, S., ... Meridian, Miss.
*Whitcomb, George D., ... 206 Lasalle Street, Chicago, Ill.
*White, William, Jr., ... Braddock, Allegheny Co., Pa.
*Whiting, S. B., ... Pottsville, Pa.
†Whitney, Eli, Jr., ... Whitneyville Armory, New Haven, Conn.
†Wickersham, J. M. K., ... 308 Branch Street. Philadelphia.
*Wickes, George T., ... Bozeman, Montana.
*Wiestling, George B., ... Mont Alto, Franklin Co., Pa.
*Wight, Sidney B., ... 463 Jefferson Avenue, Detroit, Mich.
*Wiles, Edwin L., ... Springfield Iron Co., Springfield, Ill.
*Wiley, William H., ... 15 Astor Place, New York City.
*Wilhelm, A., ... P. O. Box 178, Harrisburg, Pa.
*Wilhelm, J. Schall, ... Cornwall, Lebanon Co., Pa.
*Wilkes, John, ... Charlotte, N. C.
*Willard, H. B., ... Port Henry, Essex Co., N. Y.
*Williams, Albert, Jr., ... Box 591, Washington, D. C.
*Williams, Ben., ... Bisbee, Arizona.
*Williams, David, ... 83 Reade Street, New York City.
*Williams, D. H., ... Homestead, Allegheny Co., Pa.
*Williams, Prof. Edward H., Jr., ... P. O. Box 463, Bethlehem, Pa.
*Williams, Frederick H., ... S. St. Louis, Mo.
*Williams, Prof. J. F., ... Troy, N. Y.
*Williams, Henry, ... Butte City, Montana.
*Williams, John J., ... 32 Merchants' Exchange, San Francisco, Cal.
*Williams, John T., . Forty-fourth Street and East River, New York City.
*Williams, Lewis, ... Bisbee, Arizona.
*Williams, Samuel T., ... Albany Iron Works, Troy, N. Y.
*Williams, W. E., ... Springfield Iron Co., Springfield, Ill.
*Willis, L. E., ... Weissport, Carbon Co., Pa.
†Wilson, Henry C., ... U. S. Engineer Office, Memphis, Tenn.
*Wilson, John A., ... 435 Chestnut Street, Philadelphia.
*Wilson, John T., ... Wilson, Walker & Co., Pittsburgh, Pa.
*Wilson, Joseph M., ... Otis Iron and Steel Co., Cleveland, Ohio.
*Wilson, N. R., ... P. O. Box 1217, Leadville, Colorado.
*Wilson, William A., ... Park City, Utah.
*Winslow, Arthur, ... Hazleton, Pa.
†Wishon, Walter W., ... Colorado Springs, Colorado.
*Wister, Jones, ... 230 S. Fourth Street, Philadelphia.
*Witherbee, Frank S., ... Port Henry, Essex Co., N. Y.
*Witherbee, T. F., ... Port Henry, Essex Co., N. Y.
*Witherbee, W. C., ... Port Henry, Essex Co., N. Y.
*Witherow, J. P., ... Market and Water Streets, Pittsburgh, Pa.

*WITHERSPOON, JAMES,	Pearisburg, Giles Co., Va.
†WITTMACK, CHARLES A.,	Strasburg, Germany.
†WOLCOTT, HENRY R.,	Denver, Colorado.
*WOLF, THEODORE G.,	Scranton, Pa.
*WOLFE, ALBERT H.,	696 W. Monroe Street, Chicago, Ill.
*WOLFF, DR. FR. M.,	German Consulate General, New York City.
*WOOD, A. B.,	Ann Arbor, Mich.
*WOOD, EDWARD L.,	2716 Carson Street, Pittsburgh, Pa.
*WOOD, FREDERICK W.,	Steelton, Dauphin Co., Pa.
*WOOD, THOMAS D.,	McKeesport, Pa.
†WOOD, W. DEWEES,	111 Water Street, Pittsburgh, Pa.
*WOOD, W. J.,	Collinsville, Conn.
*WOODBURY, L. S.,	Calumet, Mich.
*WOODWARD, E. H.,	54 Cliff Street, New York City.
*WOODWARD, RICHARD W.,	South Pueblo, Colorado.
*WRIGHT, CHARLES E.,	Marquette, Mich.
†WRIGHT, HARRISON,	Wilkes-Barre, Pa.
*WRIGHT, JAMES N.,	Calumet, Mich.
*WRIGHT, WHITAKER,	Third and Walnut Streets, Philadelphia.
*WURTS, CHARLES P.,	New Haven, Conn.
*YARDLEY, THOMAS W.,	Troy, N. Y.
*YEATMAN, POPE,	Ste. Genevieve, Mo.
*YOUNG, JAMES B.,	Phœnix Roll Works, Pittsburgh, Pa.
*YOUNG, W. D.,	1 Aiken Avenue, Pittsburgh, Pa.

Honorary Members, 3.; Members, 1138; Associates, 154; Foreign Members, 50.

* * *

Deceased.

Blossom, T. M.,	1876
Briggs, Robert,	1882
Brown, A. J.,	1875
Caldwell, W. B. Jr.,	1880
Cameron, James R.,	1881
Chisholm, Henry,	1881
Clark, Henry G.,	1881
Clemes, J. P.,	1876
Daddow, S. H.,	1875
D'Aligny, H. F. Q.,	1875
De Peiger, R. F. J.,	1883
Dresser, Charles A.,	1878
Dwight, W. S.,	1883
Firmstone, William,	1877
Fuller, John T.,	1888
Gould, Robert A.,	1870
Gruner, L.,	1883
Harris, Stephen,	1874
Healy, Morris,	1881
Holley, A. L.,	1882
Hunt, Thomas,	1872
Jenney, F. B.,	1876
Jernegan, J. L.,	1881
Lee, Washington,	1872
Liebenau, Charles von,	1875
Lord, John C.	1872
Lorenz, W. Jr.,	1881
Lowe, Francis A.,	1883
McIntire, Henry M.,	1880
MacMartin, Archibald,	1881
Manthey, William,	1883
Mickley, J. W.,	1880
Moore, Charles W.,	1877
Newton, Henry,	1877
Painter, Howard,	1876
Park, James, Jr.,	1883
Phelps, Walter,	1878
Pierson, O. H.,	1882
Pleasants, Henry,	1880
Richter, C. E.,	1877
Robinson, Thomas W.,	1880
Santa Maria, Raymundo de,	1883
Schirmer, J. F. L.,	1877
Schuchard, Charles,	1883

SIEMENS, C. WILLIAM,	1883
STEITZ, AUGUSTUS,	1876
ST. JOHN, I. M.,	1880
STOELTING, HERMANN,	1875
THOMAS, DAVID,	1882
WALZ, ISIDOR,	1877
WELCH, ASHBEL,	1882
WENDEL, DR. A.,	1881
WHEATLEY, CHARLES M.,	1882
WHILLDIN, W. I.,	1882
WITHERBEE, J. G.,	1875
WORTHINGTON, HENRY R.,	1880
WRIGLEY, H. E.,	1882

RULES

ADOPTED MAY, 1873. AMENDED MAY, 1875, MAY, 1877, MAY, 1878, FEBRUARY, 1880, and FEBRUARY, 1881.

I.

OBJECTS.

THE objects of the AMERICAN INSTITUTE OF MINING ENGINEERS are to promote the Arts and Sciences connected with the economical production of the useful minerals and metals, and the welfare of those employed in these industries, by means of meetings for social intercourse, and the reading and discussion of professional papers, and to circulate, by means of publications among its members and associates, the information thus obtained.

II.

MEMBERSHIP.

The Institute shall consist of Members, Honorary Members, and Associates. Members and Honorary Members shall be professional mining engineers, geologists, metallurgists, or chemists, or persons practically engaged in mining, metallurgy, or metallurgical engineering. Associates shall include all suitable persons desirous of being connected with the Institute, and duly elected as hereinafter provided. Each person desirous of becoming a member or associate shall be proposed by at least three members or associates, approved by the Council, and elected by ballot at a regular meeting upon receiving three-fourths of the votes cast, and shall become a member or associate on the payment of his first dues. Each person proposed as an honorary member shall be recommended by at least ten members or associates, approved by the Council and elected by ballot at a regular meeting on receiving nine-tenths of the votes cast; *Provided*, that the number of honorary members shall not exceed twenty. The Council may at any time change the classification of a person elected as associate, so as to make him a member, or *vice versa*, subject to the approval of the Institute. All members and associates shall be equally entitled to the privileges of membership; *Provided*, that honorary members shall not be entitled to vote or to be members of the Council.

Any member or associate may be stricken from the list on recommendation of the Council, by the vote of three-fourths of the members and associates present at any annual meeting, due notice having been mailed in writing by the Secretary to the said member or associate.

III.

DUES.

The dues of members and associates shall be ten dollars per annum, payable in advance at the annual meeting; *Provided,* that persons elected at the meeting following the annual meeting shall pay eight dollars, and persons elected at the meeting preceding the annual meeting shall pay four dollars as dues for the current year. Honorary members shall not be liable to dues. Any member or associate may become, by the payment of one hundred dollars at any one time, a life member or associate, and shall not be liable thereafter to annual dues. Any member or associate in arrears may, at the discretion of the Council, be deprived of the receipt of publications, or stricken from the list of members when in arrears for one year; *Provided,* that he may be restored to membership by the Council on payment of all arrears, or by re-election after an interval of three years.

IV.

OFFICERS.

The affairs of the Institute shall be managed by a Council, consisting of a President, six Vice-Presidents, nine Managers, a Secretary and a Treasurer, who shall be elected from among the members and associates of the Institute at the annual meetings, to hold office as follows:

The President, the Secretary, and the Treasurer for one year (and no person shall be eligible for immediate re-election as President who shall have held that office subsequent to the adoption of these rules, for two consecutive years), the Vice-Presidents for two years, and the Managers for three years; and no Vice-President or Manager shall be eligible for immediate re-election to the same office at the expiration of the term for which he was elected. At each annual meeting a President, three Vice-Presidents, three Managers, a Secretary and a Treasurer shall be elected, and the term of office shall continue until the adjournment of the meeting at which their successors are elected.

The duties of all officers shall be such as usually pertain to their offices, or may be delegated to them by the Council or the Institute; and the Council may in its discretion require bonds to be given by the Treasurer. At each annual meeting the Council shall make a report of proceedings to the Institute, together with a financial statement.

Vacancies in the Council may occur by death or resignation; or the Council may, by a vote of the majority of all its members, declare the place of any officer vacant, on his failure for one year, from inability or otherwise, to attend the Council meetings or perform the duties of his office. All vacancies shall be filled by the appoint-

ment of the Council, and any person so appointed shall hold office for the remainder of the term for which his predecessor was elected or appointed; *Provided,* that the said appointment shall not render him ineligible at the next annual meeting.

Five members of the Council shall constitute a quorum; but the Council may appoint an Executive Committee, or business may be transacted at a regularly called meeting of the Council, at which less than a quorum is present, subject to the approval of a majority of the Council, subsequently given in writing to the Secretary, and recorded by him with the minutes.

V.

ELECTIONS.

The annual election shall be conducted as follows: Nominations may be sent in writing to the Secretary, accompanied with the names of the proposers, at any time not less than thirty days before the annual meeting; and the Secretary shall, not less than two weeks before the said meeting, mail to every member or associate (except honorary members), a list of all the nominations for each office so received, stamped with the seal of the Institute, together with a copy of this rule, and the names of the persons ineligible for election to each office. And each member or associate, qualified to vote, may vote, either by striking from or adding to the names of the said list, leaving names not exceeding in number the officers to be elected, or by preparing a new list, signing said altered or prepared ballot with his name, and either mailing it to the Secretary or presenting it in person at the annual meeting: *Provided,* that no member or associate in arrears since the last annual meeting shall be allowed to vote until the said arrears shall have been paid. The ballots shall be received and examined by three Scrutineers, appointed at the annual meeting by the presiding officer; and the persons who shall have received the greatest number of votes for the several offices shall be declared elected, and the Scrutineers shall so report to the presiding officer. The ballots shall be destroyed, and a list of the elected officers, certified by the Scrutineers, shall be preserved by the Secretary.

VI.

MEETINGS.

The annual meeting of the Institute shall take place on the third Tuesday of February, at which a report of the proceedings of the Institute and an abstract of the accounts shall be furnished by the Council. Two other regular meetings of the Institute shall be held in each year, at such times and places as the Council shall select, and notice of all meetings shall be given by mail, or otherwise, to all members and associates, at least twenty days in advance. Special meetings may be called whenever the Council sees fit; and the Secretary shall call a special meeting on a requisition signed by fifteen or more members. The notices for special meetings shall state the business to be transacted, and no other shall be entertained.

Every question which shall come before any meeting of the Institute, shall be decided, unless otherwise provided by these Rules, by the votes of a majority of the members then present. Any member or associate may introduce a stranger to any meeting; but the latter shall not take part in the proceedings without the consent of the meeting.

VII.

PAPERS.

The Council shall have power to decide on the propriety of communicating to the Institute any papers which may be received, and they shall be at liberty, when they think it desirable, to direct that any paper read before the Institute, shall be printed in the Transactions. Intimation, when practicable, shall be given, at each general meeting, of the subject of the paper or papers to be read, and of the questions for discussion at the next meeting. The reading of papers shall not be delayed beyond such hour as the presiding officer shall think proper; and the election of members or other business may be adjourned by the presiding officer, to permit the reading and discussion of papers.

The copyright of all papers communicated to, and accepted by, the Institute, shall be vested in it, unless otherwise agreed between the Council and the author. The author of each paper read before the Institute shall be entitled to twelve copies, if printed, for his own use, and shall have the right to order any number of copies at the cost of paper and printing, provided said copies are not intended for sale. The Institute is not, as a body, responsible for the statements of fact or opinion advanced in papers or discussions at its meetings, and it is understood that papers and discussions should not include matters relating to politics or purely to trade.

VIII.

AMENDMENTS.

These Rules may be amended at any annual meeting by a two-thirds vote of the members present, provided that written notice of the proposed amendment shall have been given at a previous meeting.

PROCEEDINGS

OF THE

COLORADO MEETING.

AUGUST, 1882

COLORADO MEETING.

COMMITTEE OF ARRANGEMENTS AT DENVER.

Richard Pearce, *Chairman;* H. R. Wolcott, *Secretary;* L. C. Ellsworth, John Pierce, H. Silver, E. W. Rollins, H. Beeger, A. Eilers, G. W. Young, W. S. Cheesman, S. F. Emmons.

CITIZENS' RECEPTION COMMITTEE AT DENVER.

Hon. F. W. Pitkin, Hon. N. P. Hill, Hon. John L. Routt, Hon. William Gilpin, Hon. Robert Morris, Hon. John Evans, D. H. Moffat, Jr., Samuel N. Wood, C. B. Kountze, W. B. Daniels, D. C. Dodge, C. W. Fisher, A. A. Egbert, Hon. W. A. H. Loveland, J. S. Brown, K. J. Cooper, R. W. Woodbury, Hon. T. M. Patterson, O. H. Rothacker, Dr. D. H. Moore, J. A. Cooper, Hon. H. A. W. Tabor, John Arkins, G. G. Symes, James Archer, Hon. J. B. Chaffee, W. S. Decker, G. W. Clayton, James Duff, Hon. Edward O. Wolcott, W. H. Bush, Aaron Gove, Chester S. Morey, F. Z. Salomon, William M. Bliss, Colonel William Moore, C. F. Hendrie, A. G. Langford, J. W. Nesmith, J. W. Savin, L. H. Eicholtz, A. Sweeney, Hon. Moses Hallett, E. F. Bishop, Hon. E. T. Wells, J. A. Thatcher, Albert Johnson, Gustav Billing, Hon. Frank Hall, W. L. Campbell, Colonel A. H. Jones, J. L. Jerome, Willard Teller, G. B. Reed, P. H. Van Diest, Hon. C. H. Toll, D. A. Gage, W. H. James, W. H. Lessig, J. C. Wilson, D. Sullivan, Hon. Assyria Hall, J. E. Pearson, Frederick Steinhauer, W. N. Byers, Wolfe Londoner, Hon. W. E. Beck, G. W. Kassler, George Tritch, W. G. Fisher, Birks Carnforth.

The opening session of the meeting was held at the Denver University, in Assembly Hall, on Saturday evening, August 19th. Mr. Richard Pearce, Chairman of the Local Committee, called the meeting to order, and introduced Hon. F. W. Pitkin, Governor of the State of Colorado, who addressed the Institute, extending to the members present a cordial welcome to Colorado.

Mr. R. P. Rothwell, President of the Institute, after replying to the welcome of Governor Pitkin, spoke of the early history of the Institute, which was organized eleven years before in his office in Wilkes-Barre, Pa., of the objects then had in view, and of the results since attained, and also dwelt on the importance of the elevation of the working classes by means of industrial education and the improvement of their homes.

President Rothwell then proceeded to speak as follows of the enormous development of some of those industries in which the Institute was interested, and pointed out the effect of that greater intelligence, technical knowledge, and skill, which he had been advocating, upon economy in the production of the useful minerals and metals, and upon the safety and welfare of those engaged in these industries:

Let us take that industry which forms the basis of modern civilization, and whose development measures the prosperity and forecasts the future of nations. Every one knows that I refer to the production of coal.

Since the history of the coal trade has taught the same lesson in every country, and not to tax your patience with many details, I shall refer only to that of Great Britain, where it has attained by far the greatest development; and to that of our own country, where our interest is greatest.

Though coal was known in Great Britain in the times of the Roman occupation of the island, and was mined to some extent during the twelfth century, yet for several hundred years of those dark ages its uses were so limited, and the prejudices against its introduction so great, that its production in 1700 amounted to only about 2,500,000 tons; and one hundred years later, or in 1800, it had reached only 10,000,000 tons annually.

In those early years of the trade, the colliers were looked upon as chattels, to be transferred with the mines, and their condition was practically little better than one of actual slavery. They were the most ignorant and degraded class in the kingdom; both women and children working with the men in the mines, and all earning but a miserable pittance, and living in the most wretched manner. Yet though the mines were then shallow, and the coal was much easier obtained than it now is, coal cost far more per ton than it now does, and there was a long period during which its price in London varied from \$10 to \$12 per ton, or more than twice as much as it costs to-day, with wages many times greater than formerly, and the condition of the working classes infinitely improved. It was only within the enlightened reign of that ideal ruler and most excellent woman, Queen Victoria, that the demoralizing and disgraceful employment of women and children in the mines was prohibited by law. Belgium alone of enlightened European nations still permits this disgraceful practice.

The 10,000,000 tons production of coal at the commencement of the century had reached 64,000,000 in 1850, when the government

inspection of British mines was established as a means of preventing the frequent frightful accidents which up to that time had characterized coal mining.

The parliamentary commissions which, in 1835 and in 1849, elicited and put upon record all the knowledge on mining questions then obtainable in Great Britain, were the first meetings of English mining engineers, and they were quickly followed by a notable improvement in mining. In the year 1851, with 216,000 persons employed in and about the coal mines, there were 984 lives lost, or one death for 219 persons employed; while the average for the ten years, 1851–60, was one life lost to 245 persons employed. During the next ten years, the average was 300 persons employed for each life lost; while during the third decade of inspection the proportion was one death to 425 persons employed. During the year 1881, this proportion had declined to one in 519; or the effect of greater technical knowledge was to reduce to about one-half the death-rate from accidents in British coal mines; while the output of the coal mines, which, at the commencement of the inspection period, had amounted to 64,000,000 tons, last year had attained the enormous total of 169,000,000 gross tons, of which 154,000,000 tons were coal. The ratio of the number of accidents to the number of persons employed is even more favorable than that of deaths to persons employed, showing conclusively the benefits arising from greater skill in the management of the mines and from greater intelligence among the working classes.

To return to our own country: I hold in my hands a table showing the production of anthracite coal in Pennsylvania from the commencement of the trade to the close of 1881:

The Anthracite Coal Production of Pennsylvania, in Tons of 2240 Pounds.

BY RICHARD P. ROTHWELL.

YEARS.	THE WYOMING REGION. Luzerne and Sullivan Counties.		THE LEHIGH REGION. Carbon, Columbia, and Luzerne Counties.		THE SCHUYLKILL REGION. Schuylkill, Northumberland, Columbia, Dauphin, and Lebanon Counties.		ALL THE REGIONS.
	Shipments.	Total production.	Shipments.	Total production.	Shipments.	Total production.	Total production.
Before 1820	....	[illegible]	....	[illegible]	....	[illegible]	[illegible]
1820	....	[illegible]	365	[illegible]	....	[illegible]	[illegible]
1821	....	[illegible]	[illegible]	[illegible]	....	[illegible]	[illegible]
1822	....	[illegible]	[illegible]	[illegible]	....	[illegible]	[illegible]
1823	....	[illegible]	[illegible]	[illegible]	....	[illegible]	[illegible]
1824	....	[illegible]	[illegible]	[illegible]	....	[illegible]	[illegible]
1825	....	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1826	....	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1827	....	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1828	....	6,200	30,233	33,233	47,181	52,481	91,914
1829	7,000	16,800	25,110	29,110	78,293	87,293	133,203
1830	42,000	58,200	41,750	46,850	89,984	104,584	209,634
1831	54,000	78,300	40,966	47,166	81,854	104,854	230,320
1832	84,500	121,700	75,000	82,700	209,271	243,771	448,171
1833	111,777	161,777	123,000	132,100	250,588	298,333	592,210
1834	43,700	53,008	106,244	128,874	226,692	274,977	456,859
1835	90,000	108,900	131,250	158,812	339,508	410,805	678,517
1836	103,861	125,360	148,211	178,891	432,045	521,478	825,729
1837	115,387	139,041	223,902	269,802	523,152	630,398	1,039,241
1838	78,207	94,083	213,615	256,979	433,875	521,951	873,013
1839	122,300	146,760	221,025	265,230	454,538	545,446	957,436
1840	148,470	177,867	225,318	269,932	467,796	560,421	1,008,220
1841	192,270	229,955	143,037	171,072	607,005	725,978	1,127,005
1842	252,599	301,856	272,546	325,692	551,504	659,017	1,286,595
1843	285,605	340,441	267,793	319,209	687,312	819,276	1,478,926
1844	365,911	435,434	377,002	418,633	853,465	1,015,623	1,899,690
1845	451,836	536,329	429,453	509,761	1,093,796	1,298,336	2,344,426
1846	518,389	614,291	517,116	612,783	1,249,154	1,480,247	2,707,321
1847	583,067	689,185	633,507	748,805	1,598,278	1,889,165	3,327,155
1848	685,196	808,531	670,321	790,979	1,672,191	1,973,185	3,572,695
1849	732,910	862,635	781,656	920,009	1,650,101	1,942,168	3,724,812
1850	827,823	972,692	690,456	811,286	1,769,691	2,079,387	3,863,365
1851	1,156,167	1,355,028	964,224	1,130,071	2,308,525	2,705,591	5,190,690
1852	1,284,500	1,502,865	1,072,136	1,254,399	2,536,653	2,967,884	5,725,148
1853	1,475,732	1,723,655	1,054,309	1,231,433	2,555,450	2,984,765	5,939,853
1854	1,603,478	1,868,052	1,207,186	1,406,372	3,066,208	3,572,132	6,846,556
1855	1,771,511	2,060 267	1,284,113	1,493,423	3,551,893	4,130,852	7,684,542
1856	1,972,581	2,288,194	1,351,970	1,568,285	3,571,800	4,143,288	7,999,767
1857	1,952,603	2,261,114	1,318,541	1,526,871	3,373,797	3,906,857	7,691,842
1858	2,186,094	2,527,125	1,380,030	1,595,315	3,236,843	3,741,790	7,864,230
1859	2,731,236	3,151,846	1,628,311	1,879,071	3,448,708	3,979,809	9,010,726
1860	2,941,817	3,388,973	1,821,674	2,098,569	3,749,632	4,319,576	9,807,118
1861	3,055,140	3,513,411	1,738,377	1,999,134	3,160,797	3,634,916	9,147,461
1862	3,145,770	3,608,198	1,351,054	1,549,658	3,432,584	3,937,175	9,095,031
1863	3,759,610	4,301,754	1,894,713	2,169,446	3,911,683	4,478,877	10,993,077
1864	3,960,836	4,526,635	2,054,669	2,348,233	4,161,970	4,756,532	11,631,400
1865	3,255,658	3,720,717	1,822,535	2,082,858	4,356,959	4,979,457	10,783,032
1866	4,736,616	5,413,958	2,128,867	2,433,280	5,461,209	6,245,599	14,092,837
1867	5,328,322	6,089,272	2,062,446	2,356,867	5,161,671	5,899,505	14,345,614
1868	5,990,813	6,816,699	2,507,582	2,865,820	5,335,737	6,097,947	15,810,166
1869	6,068,369	7,279,543	1,929,523	2,313,989	5,653,855	6,782,116	16,375,678
1870	7,554,909	8,811,024	2,990,878	3,489,364	4,728,242	5,516,312	17,819,700
1871	6,713,773	7,690,251	2,249,356	2,568,764	6,234,974	7,120,340	17,379,355
1872	9,191,171	10,750,050	3,610,674	4,202,824	6,126,468	7,131,209	22,084,083
1873	10,047,241	11,744,141	3,263,168	3,801,447	6,294,454	7,335,333	22,880,921
1874	9,513,012	10,241,032	3,868,749	4,139,561	6,810,087	7,286,793	21,667,386
1875	10,519,998	11,062,520	2,731,311	2,867,876	6,393,441	6,713,113	20,643,509
1876	8,100,000	8,530,000	3,800,000	3,970,000	6,200,000	6,500,000	19,000,000
1877	7,900,000	8,323,000	4,200,000	4,400,000	8,200,000	8,600,000	21,323,000
1878	7,750,000	8,250,000	3,245,000	3,440,000	6,520,000	6,910,000	18,600,000
1879	12,575,000	13,300,000	4,550,000	4,825,000	9,015,300	9,556,218	27,681,218
1880	11,419,279	12,104,436	4,463,221	4,731,014	7,554,742	8,008,027	24,843,177
1881	13,561,241	14,378,100	5,527,665	7,190,800	8,116,615	8,684,040	30,261,940
	179,122,318	199,721,905	81,571,582	92,618,041	169,652,205	190,934,521	483,274,467

Wyoming includes the Loyalsock Region in Sullivan County, opened in 1871. The production of this region has been as follows: 1871, 23,122 tons; 1872, 51,527 tons; 1873, 32,058 tons; 1874, 36,268 tons; 1875, 16,522 tons; 1876, 30,000 tons; 1877, 23,000 tons; 1878, 37,000 tons; 1879, 50,000 tons; 1880, 50,000 tons; 1881, 64,325 tons.

These statistics I have compiled with great care—in many instances, from original manuscripts. They show the wonderful progress in this industry, which in sixty years grew from a few tons to 30,000,000, or to about two-fifths of the entire coal production of this country, which in 1881 reached the grand total of about 75,000,000 net tons.

The increase in skill attained during even the few years since our Institute has been organized is most apparent in the increased output of individual collieries. Ten or fifteen years ago, an output of from 300 to 400 tons a day, of ten working hours, was considered good work for either a shaft or a breaker. Now we have collieries where 1500 and 2000 tons of merchantable coal are raised from a single shaft, broken, sized, and cleaned in a single breaker in ten hours. This is equivalent to from 200 to 250 tons an hour as the output of a shaft raising one car at a time. Some idea of the speed with which work is performed at one of these collieries may be gained from the fact that the time occupied in taking the loaded car, carrying from 2 to 3 tons of coal, off the cage, and putting the light car on, is less than six seconds in regular work; or the time from the moment the cage shows itself coming up the shaft, until it disappears going down, is, almost as uniformly as the beat of a pendulum, about seven seconds.

The work of breaking, sizing, and cleaning anthracite for market is done for about seven cents a ton, all handling included. In no other portion of the world are the mechanical appliances for mining and preparing coal as perfect as in Pennsylvania; yet, even there, many improvements have still to be made. The waste in mining and in the preparation of anthracite is fully 60 per cent. of the coal in the bed, and but little has been done to lessen this loss by the adoption of any less wasteful system of mining than that in use since our mines were first opened. No doubt the introduction of the electric light will make it possible to work our coal-breakers and mines both night and day, and thereby considerably reduce the amount of capital invested for a given output. In our bituminous mines, the introduction of coal-cutting machines is effecting a very notable economy. The safety of miners has been greatly promoted by the better ventilation of the mines, the improvements in mining machinery, the more skilful management of the mines, and the growing intelligence of the men themselves.

The following table shows the increase in the production of bituminous coal from 1870 to 1880, according to the returns made by the Census Bureau, in short tons:

States.	1870.	1880.
Alabama,	11,000	323,972
Arkansas,		14,778
California,		236,950
Colorado,		462,747
Georgia,		154,644
Illinois,	2,624,163	6,115,377
Indiana,	437,870	1,454,327
Iowa,	263,487	1,461,116
Kansas,	150,582	771,142
Kentucky,	32,938	946,288
Maryland,	2,345,153	2,228,917
Michigan,	28,150	100,800
Missouri,	621,930	556,304
Montana Territory,		224
Nebraska,	1,425	200
North Carolina,		350
Ohio,	2,527,285	6,008,595
Oregon,		43,205
Pennsylvania,	7,800,356	18,425,163
Tennessee,	133,148	495,131
Virginia,	61,803	43,079
Washington Territory,		145,015
West Virginia,	608,878	1,839,845
Wyoming Territory,		589,595
Total,	17,648,468	42,417,764

Production of Coal, Metals, and Petroleum from 1776 *to* 1881.

YEAR.	Anthracite. Unit, 1000 tons.	Pig-iron. Unit, 1000 tons.	Lead. Unit, 1000 tons.	Copper. Unit, 1000 tons.	Quicksilver. Unit, 1000 flasks.	Gold. Unit, $1000 coin.	Silver. Unit, $1000 coin.	Petroleum. Unit, 1000 barrels.
1776 to 1851	38,279	10,961	391	6	49	175,000	....	....
1852	5,725	541	14	1	20	60,000	....	....
1853	5,940	723	15	2	22	65,000	....	....
1854	6,847	662	14	2	30	60,000	....	....
1855	7,684	700	14	3	33	55,000	....	....
1856	8,000	789	14	4	30	55,000	....	....
1857	7,695	713	14	5	28	55,000	....	....
1858	7,864	630	14	6	31	50,000	....	....
1859	9,011	751	14	6	13	50,000	100	3
1860	9,807	821	14	7	10	46,000	150	650
1861	9,147	653	14	8	35	43,000	2,000	2,114
1862	9,026	703	14	9	42	39,200	4,500	3,057
1863	10,953	846	14	6	41	40,000	8,500	2,611
1864	11,631	1,014	14	7	47	46,100	11,000	2,116
1865	10,783	832	13	7	53	53,200	11,250	3,498
1866	14,231	1,200	14	7	47	53,500	10,000	3,598
1867	14,346	1,305	14	8	47	51,700	13,550	3,347
1868	15,810	1,431	15	9	48	48,000	12,000	3,716
1869	16,376	1,711	16	12	31	49,500	13,000	4,215
1870	17,820	1,696	16	13	30	50,000	16,000	5,659
1871	17,380	1,708	18	13	32	43,500	22,100	5,795
1872	22,084	2,540	23	12	32	36,000	25,750	6,539
1873	22,881	2,561	47	16	28	35,000	36,500	9,789
1874	21,667	2,401	53	18	28	39,600	32,800	10,910
1875	20,644	2,109	58	16	15	33,400	41,400	8,788
1876	19,000	1,869	61	18	75	44,329	41,506	8,972
1877	21,323	2,067	75	19	79	45,300	46,075	13,136
1878	18,600	2,301	83	19	64	41,000	40,000	15,165
1879	27,825	2,742	90	20	74	32,540	38,624	19,712
1880	24,843	3,835	95	25	60	33,522	40 005	24,229
1881	30,262	4,144	105	31	59	31,870	45,078	27,264

NOTE.—The ton in this table is the gross ton of 2240 pounds avoirdupois; the flask of quicksilver, 76½ pounds avoirdupois; the barrel of petroleum, 42 gallons.

For the table immediately preceding I am indebted to Dr. R. W. Raymond, who has condensed and revised the similar table of President Hewitt at Philadelphia in 1876,* and continued it to the present time.

The statistics of other useful minerals and metals show an equally marvellous advance during the past thirty years. The production of pig iron, which in 1852 was 541,000 net tons, in 1861 was 653,000 tons, and in 1871 was 1,708,000 tons. Ten years later, in 1881, we produced no less than 4,144,000 tons, an increase during thirty years of nearly. 800 per cent.

Lead, which appears in this table at 14,000 tons in 1852, varied but little from that figure until the construction of railroads into the argentiferous lead-mining districts of the West about 1870. Nevada, Utah, and more recently, Colorado, with its Leadville bonanzas, rapidly raised the production from 18,000 tons in 1871, to 47,000 tons in 1873, 75,000 tons in 1877, and 105,000 tons in 1881.

Our production of copper steadily increased from 1000 tons in 1852 to 31,000 tons in 1881; the enormous output of that unrivalled mine, the Calumet and Hecla, steadying the production and neutralizing the fluctuations of the lesser mines.

Quicksilver has shown wide fluctuations, due more to trade combinations than to the condition of the mines. In 1852, the output amounted to 20,000 flasks; but it went as low as 10,000 flasks in 1860, and rose to 53,000 flasks five years later; from this, it declined to 15,000 flasks in 1875, though in the following year it grew to 75,000 flasks. Last year, we produced 59,000 flasks.

Gold is the only metal in which our production has been declining. In 1852, it amounted to $60,000,000; but, with some fluctuations, it has now declined to less than $32,000,000 annually.

The production of silver, on the contrary, has largely increased. Commencing in 1859 with $100,000, it has now attained $45,000,000. In 1877 only were these figures exceeded, and then only by about $1,000,000.

The production of petroleum, that great American industry, has grown with wonderful rapidity. In 1859 it commenced with only 3000 barrels, and after an almost uniform increase, it attained last year the enormous figure of 27,000,000 barrels. Scientific investigation has recently raised a note of warning in this industry, asserting the limited area of oil-producing territory and its approaching exhaustion.

* *Transactions*, vol. v., p. 194.

I have now enumerated a few of the products of our mining and metallurgy, which alone cost consumers some $700,000,000 annually, and support several millions of our people.

The promotion of economy in the production of these useful minerals and metals, and the safety and welfare of those engaged in these industries, are the worthy objects for which our Institute was formed. How wonderfully successful it has been, is shown in the records of professional experience and achievement, crystallized in the growing volumes of our most useful *Transactions*. No one studying these records can doubt either the continued usefulness of this Institute, the grand future of our profession, or the greatness that awaits a country whose unrivalled natural resources are developed with an intelligence in every department of industry and in every class of workers unequalled in the history of the world.

At the conclusion of this address there was read a communication from the Denver Club, offering to the members of the Institute the freedom of the club during their stay in Denver.

On motion of Dr. R. W. Raymond the thanks of the Institute were voted to Governor Pitkin for his address, and to the Citizens' Committee for their kind reception of the Institute, after which the meeting adjourned.

CENTRAL CITY EXCURSION.

Local Committee.

G. E. Randolph, *Chairman;* F. G. Nagle, William Fullerton, Thomas H. Potter and F. C. Craven.

On Monday, at 8 o'clock A.M., the party left Denver by special train, furnished by the courtesy of the Union Pacific Railway Company, for Central City, arriving about noon. After dinner at the Teller House, carriages were in waiting, and three excursions were organized: the first visited the Gregory and Bobtail mines and the stamp-mills at Black Hawk, under the guidance of Mr. F. G. Nagle; the second visited the Gunnell, Kansas, and California mines, under the guidance of Messrs. Craven and Fullerton; the third party were conducted by Mr. Potter to Russell Gulch and Bellevue Mountain.

In the evening, at 8 o'clock, a session was held in the Central City Opera House. The following persons, proposed for members and associates of the Institute, and recommended by the Council, were unanimously elected.*

* In the following list are included those elected at subsequent sessions of this

MEMBERS.

Archibald A. Alexander,	Prescott, Arizona.
Joseph H. Allen,	Ore Knob, Ashe County, N. C.
Albert Arents,	Denver, Colorado.
Hugo Arnolds,	Leadville, Colorado.
Gilbert E. Bailey,	Cheyenne, Wyoming.
Thomas H. Bates,	Empire, Colorado.
Hermann Beeger,	Denver, Colorado.
Andrew M. Bell, care of R. Pearce,	Denver, Colorado.
Henry P. Bicknell,	South Pueblo, Colorado.
Gustav Billing,	Denver, Colorado.
J. Berdell,	Denver, Colorado.
Albert A. Blow,	Leadville, Colorado.
William R. Boggs, Jr.,	Leadville, Colorado.
Wesley Brainerd,	Gold Hill, Colorado.
John M. Brinker,	Fairmount City, Clarion County, Pa.
F. D. Browning,	New York City.
Fredrick Bruckman,	Leadville, Colorado.
G. W. Bryan,	Leadville, Colorado.
Alexander Bryden,	Leadville, Colorado.
F. G. Bulkley,	Leadville, Colorado.
E. E. Burlingame,	Denver, Colorado.
Frank R. Carpenter,	Georgetown, Colorado.
James P. Carson,	New York City.
Arthur Chanute,	Leadville, Colorado.
Marshall Childs,	Pittsburgh, Pa.
Frederick W. Clark,	Alma, Park County, Colorado.
Edward T. Clymer,	Temple, Berks County, Pa.
Charles C. Coffin,	Muirkirk, Md.
Francis Collingwood,	New York City.
Clarence K. Colvin,	Idaho Springs, Colorado.
William Connell,	Scranton, Pa.
William S. Cranz,	Tucson, Arizona.
Joseph L. Cunningham,	Ringwood, N. J.
A. H. Danforth,	South Pueblo, Colorado.
D. R. Davidson,	Pittsburgh, Pa.
P. B. de Schweinitz,	South Pueblo, Colorado.
E. V. d'Invilliers,	Philadelphia.
George Douglas,	Culiacan, Sinaloa, Mexico.
John M. Dumont,	Idaho Springs, Colorado.
J. F. Eastwood,	Bethany, W. Va.
Edward Eddy,	Denver, Colorado.
J. M. S. Egan,	Georgetown, Colorado.
C. F. Findlay,	Constableville, Lewis County, N. Y.
Sandford Flemming,	Ottawa, Canada.
Emerson L. Foote,	St. Louis, Mo.
R. G. Ford,	Bell's Mills, Blair County, Pa.
Frank C. Garbutt,	Denver, Colorado.
Miles W. Goodyear,	New York City.
L. R. Grabill.	Querida, Custer County, Colorado.

J. D. Groesbeck,	Mapimi, Durango, Mexico.
Reuben Haines,	Philadelphia.
Albert C. Hale,	Golden, Colorado.
C. C. Hall,	Chicago, Ill.
Frederick A. Halsey,	New York City.
William S. Halsey,	Tremont, Pa.
Gustave Hambach,	St. Louis, Mo.
John E. Hardman,	Lowell, Mass.
A. W. Hare,	Kokomo, Colorado.
O. H. Harker,	Leadville, Colorado.
F. M. Hausling,	Tin Cup, Colorado.
Carl Henrich,	Leadville, Colorado.
John T. Herrick,	Leadville, Colorado.
Albert F. Hill,	New York City.
J. L. Hollenbeck,	Audenried, Pa.
Thomas J. Houston,	Thurlow, Pa.
Herman Huber,	Leadville, Colorado.
D. W. Humphrey,	Scranton, Pa.
N. S. Hungerford,	Socorro, N. M.
Axel O. Ihlseng,	Animas Forks, Colorado.
H. S. Kearney,	Leadville, Colorado.
John Kenedy,	Montreal, Canada.
Thomas Kiddie,	New Brighton, Staten Island.
Hiram Kimball,	Cleveland, O.
James C. Kingsley,	Brooklyn, N. Y.
Maxwell Kinkead,	Altoona, Pa.
Ferdinand Kœrner,	Deloro, Canada.
William M. Krauser,	Utica, N. Y.
William H. Lee,	St. Louis, Mo.
Edward Kneass Landis,	Pottstown, Pa.
W. J. Latta,	Altoona, Pa.
Nicholas Lennig,	Philadelphia.
Alexander von Leonhard,	St. Louis, Mo.
Oscar Loiseau,	Ougrée, Belgium.
William H. Long,	Fairlee, Vt.
R. F. Lord,	San Francisco, California.
Theodore H. Lowe,	Idaho Springs, Colorado.
Thomas Manning,	Denver, Colorado.
Jean A. Mathieu,	Detroit, Mich.
L. C. McKinney,	Georgetown, Colorado.
William Milnes, Jr.,	Milnes, Va.
Charles J. Moore,	Leadville, Colorado.
Alfred J. Moses,	New York City,
Milton Moss,	Golden, Colorado.
Horace I. Moyer,	Hazelton, Pa.
Frederick O. Norton,	New York City.
P. J. Oettinger,	New York City.
Walter T. Page,	Leadville, Colorado.
John M. Palmer,	Denver, Colorado.
Richard A. Parker,	Georgetown, Colorado.
Russell Parker,	Leadville, Colorado.

H. D. Pearsall,	Tin Cup, Colorado.
John E. Pearson,	Denver, Colorado.
J. G. Pohle,	Georgetown, Colorado.
Richard A. Pomeroy,	Georgetown, Colorado.
Francis L. Potts,	Barneston, Pa.
Charles J. Pusey,	New York City.
J. R. Rand,	New York City.
George C. Randolph,	Central City, Colorado.
E. P. Rathbone,	London, England.
Ross B. Reid,	Dunbar, Pa.
Armitage Rhodes,	Montreal, Canada.
James Riley,	Glasgow, Scotland.
A. N. Rogers,	Central City, Colorado.
E. M. Rogers,	Central City, Colorado.
C. J. Roney,	Chicago, Ill.
W. R. Roney,	Chicago, Ill.
W. W. Rose, Jr.,	Denver, Colorado.
Axel Sahlin,	Johnstown, Pa.
Raymundo de Santa Maria,	New York City.
Charles P. Sawyer,	New York City.
Charles Schuchard,	Corralitos, Chihuahua, Mexico.
C. A. Scott,	Halifax, Nova Scotia.
A. J. Seligman,	Helena, Montana.
Nathaniel W. Shed,	Nashua, N. H.
Gardiner H. Sheldon,	Corralitos, Chihuahua, Mexico.
J. Alden Smith,	Denver, Colorado.
C. H. Smyth,	Clinton, Oneida County, N. Y.
Anson P. Stevens,	Lawson, Colorado.
John D. Swain,	Nashua, N. H.
Frank H. Thomas,	Hokendauqua, Pa.
Pieter H. van Diest,	Denver, Colorado.
George G. Vivian,	Freeland, Colorado.
A. Walter,	Altoona, Pa.
F. W. A. Wahlberg,	Washington, D. C.
A. E. Walton,	London, England.
Henry Walter Webb,	New York City.
A. Werner,	Mapimi, Durango, Mexico.
Jerome Wheelock,	Worcester, Mass.
Albert Williams, Jr.,	U. S. Geological Survey, Washington, D. C.
Ben. Williams,	Bisbee, Arizona.
J. M. Wilson,	Cleveland, O.
Dr. Fr. Mor-Wolff,	Berlin W., Prussia.
A. B. Wood,	Ann Arbor, Mich.
R. F. Wrigley,	Silverton, Colorado.

ASSOCIATES.

Charles H. Baker,	Philadelphia.
Richard D. Baker,	Philadelphia.

Charles E. Boyle,	Uniontown, Pa.
William Bracken,	Philadelphia.
C. P. Bryan,	Idaho Springs, Colorado.
E. A. Buck,	Gunnison, Colorado.
L. Duncan Bulkley,	New York City.
F. von A. Cabeen,	Philadelphia.
Robert C. Canby,	Philadelphia.
W. A. Clark,	Butte, Montana.
James H. Dalliba,	Cleveland, O.
Winchester Dickerson,	Philadelphia.
J. H. Dudley,	Denver, Colorado.
Leon P. Feustman,	Philadelphia.
J. P. Flynn,	Ashcroft, Colorado.
Albin Garrett,	Philadelphia.
E. H. Garthwaite,	Freiberg, Saxony.
Frank W. Gibb,	Little Rock, Arkansas.
Edward B. Goodyear,	Naugatuck, Conn.
H. M. Griffin,	Georgetown, Colorado.
Edward L. Herndon,	Cherry Valley Mines, Crawford County, Mo.
C. John Hexamer,	Philadelphia.
George H. Holt,	Crested Butte, Colorado.
M. H. Housman,	Pittsburgh, Pa.
William H. Hulick,	Easton, Pa.
William James,	St. James, Mo.
F. E. Lehman,	New York City.
Samuel W. Lewis,	New York City.
F. A. Massie,	University of Virginia, Charlottesville, Va.
Joseph J. McDowell,	St. Louis, Mo.
Thomas A. McElmell,	Tucson, Arizona.
John C. McKenzie,	New York City.
Archibald Means,	Peru, Illinois.
John J. Mickley,	Hokendauqua, Pa.
Thomas J. Milnes,	Milnes, Va.
William Moore,	Idaho Springs, Colorado.
William R. Painter,	Carrollton, Mo.
Peter E. Phillips,	Johnstown, Pa.
O. H. Pierson,	New York City.
W. F. Pinkham,	Nashua, N. H.
Pleasant Porter,	Wealaka, Ind. Ter.
Edward Reed,	Denver, Colorado.
Joseph A. Shinn,	Allegheny City, Pa.
Lorin X. Smith,	Colorado Springs, Colorado.
Frederick W. Sperr,	Smithsonian Institution, Washington, D. C.
John T. Stambaugh,	Youngstown, O.
Charles F. Stewart,	Cleveland, O.
E. H. Stowe,	Pittsburgh, Pa.
Samuel Tate,	Denver, Colorado.
Walter W. Wishon,	Rolla, Mo.
Henry R. Wolcott,	Denver, Colorado.
Jesse B. Young,	Altoona, Pa.

The status of the following persons was changed from associate to member: J. Trowbridge Bailey, Thomas P. Conant, F. J. Dominick, H. A. Keller, and S. A. Reed.

Upon the announcement by the President of the death of David Thomas since the last meeting of the Institute, Mr. J. C. Bayles offered the following preamble and resolutions:

The American Institute of Mining Engineers, desiring to place upon its records a fitting expression of respect for the memory of its first President, David Thomas, whose death at the venerable age of eighty-seven has occurred since our last meeting, directs that the following be spread upon its minutes and published in its *Transactions:*

Resolved, That in the death of David Thomas the country has lost a citizen whose life was an example of all the virtues which adorn society and strengthen the State, and whose work contributed in an unusual degree to the development of our metallurgical industries.

Resolved, That in his death, which all who knew him count a personal bereavement, the American Institute of Mining Engineers has lost a member whose name was an honor to its roll, and whose great service to the iron trade of the country in demonstrating the value of anthracite as a metallurgical fuel laid the foundation of one of the greatest of our national industries.

Resolved, That we remember with pleasure that his life was prolonged so far beyond the average; that it was so rich in all that contributes to the happiness of good men; that in old age he was permitted to enjoy the companionship of his gentle wife, to whom we tender our deepest sympathies; and that his declining years were blessed by filial love and the devotion of friends.

Dr. R. W. Raymond, in seconding these resolutions, said:

In the absence of Mr. Mickley, who was David Thomas's associate in business and intimate friend, it falls perhaps appropriately upon me to say a word or two in seconding the resolutions just offered. I regret extremely that I am not better prepared to do this, and that the duty has been thrust upon me so suddenly that I can scarcely find words worthy of the subject and the place. My own connection with Mr. Thomas is known to many of you. When this Institute was formed, eleven years ago, our present President took the chair as a temporary officer as long as that first session continued; but when the committee appointed for the purpose came together to elect permanent officers for this new society, we turned with one accord to the man whose name would do more than any other name to unite in support of our new enterprise the enthusiasm of science with the experience of practice, and none of you who look now upon the vast prosperity of this society can realize how supremely important it was thus to secure at the outset the combination of those two elements, the lack of either of which might have been fatal to our hopes and plans. I venture to say that no mere

society of young scholastic graduates, no society of men learned in what they had learned from other men, no society of men looking down upon the hard-handed and unlettered practical operators of the country could have taken root and become strong, and useful, and beautiful as ours has done. It was because the men who, like David Thomas, had worked from boyhood with their own hands, and had come to learn from long experience the value of science, and of books, and of the records and interchange of experience of other men, cordially came forward and took our weak young hands into their strong old hands, that we began from the first to win the confidence of both the classes, whose co-operation was so necessary to us. Mr. Thomas was then already an old man, ready to lay aside the cares and labors of life, and well deserving the rest and comfort which wealth, and friendship, and assured success of every kind in life might have well bestowed upon him; but he took hold of this young enterprise with such an enthusiasm, and sympathy, and warmth of feeling as to inspire even his young co-laborers. He did, indeed, make one condition; namely, that at his advanced age great physical labor should not be required of him; but those of us who attended the first few meetings of the Institute, at Bethlehem, at Troy, and elsewhere, will bear witness that his indomitable agility, activity, and cheerfulness were such as to make his age almost a mockery. We could scarcely believe that he needed to be excused from any labor. He seemed to be endowed with all the freshness of an everlasting youth. As I happened to be the first Vice-President on the list, it fell to me to do the physical labor during Mr. Thomas's administration, and I afterwards became his immediate successor. I can never forget with what kindness—constant, unvarying, and cordial—he treated me in all our intercourse. But my personal relations fade into insignificance when I recollect what he has done through his whole life for the industry of this country; what was his invariable, stimulating, refreshing kindness to young men; and what was his courage and cheerfulness up to the very last.

We knew that his affections were with us, and when, at last, he laid down the nominal badge of his office among us, it was with a unanimous and enthusiastic vote that we made him our first honorary member—our only honorary member in this country. We never have bestowed—we never shall bestow—an honor better deserved.

I can scarcely occupy time to-night with any discussion of the history of Mr. Thomas's contributions to American industry. These resolutions, while they pay him a meed of praise that is justly his

due, are certainly not intended to exclude from similar praise his early co-laborers like our worthy friend, William Firmstone, who preceded Mr. Thomas into the land of shadows; such men laid the foundation of our great industries in the East. What they wrought and what will spring from what they wrought we can scarcely measure in words, we can scarcely picture in dreams; but now that they are gone, we who have laid them to rest remember them rather as friends than as public benefactors.

I am very glad, sir, to second these resolutions, and I only wish that time and more thorough preparation had enabled me to do it in worthier words.

The resolutions were carried unanimously.

A paper by Mr. A. N. Rogers, of Central City, on The Mines and Mills of Gilpin County, was then read by Mr. E. M. Rogers, and discussed by Messrs. Raymond, Maynard, Rothwell, and Pearce.

GEORGETOWN EXCURSION.

Local Committee.

C. A. Martine, *Chairman;* W. A. Hamill, Henry Fulton, H. H. Atkins, E. Le Neve Foster, R. F. Lord, R. A. Pomeroy, J. G. Pohle, C. T. Bellamy, F. H. Allison, G. W. Hall, Anson P. Stephens, C. P. Baldwin.

The special train placed at the disposal of the Institute by the Union Pacific Railway left Central City on Tuesday morning at 7 o'clock, arriving at Georgetown at 10 A.M. Here two parties were formed, one visiting the Terrible and Dunderberg mines, and the other Green Lake, at both of which places lunch was provided. On the return to Denver a stop of three hours was made at Idaho Springs, where the baths were visited and the members and ladies charmingly entertained by Governor T. B. Bryan and by Colonel William Moore. Denver was reached at 10.30 P.M.

LEADVILLE EXCURSION.

Local Committee.

R. Neilson Clark, *Chairman;* W. B. Page, *Secretary.*

Committee on Directory: R. Neilson Clark, *Chairman;* Franz Fohr, Henry A. Vezin.

Committee on Finance: Henry A. Vezin, *Chairman;* D. H. Dougan, J. B. Bissell, E. L. Campbell, Nicholas Firm, Robert Bunsen, W. B. Page, F. N. Ketcham.

Committee on Entertainment: H. S. Kearney, *Chairman;* W. S. Ward, J. B. Grant,

E. C. Reynolds, M. E. Smith, Franz Fohr, A. A. Blow, O. H. Hahn, L. C. Leonard, E. C. Gilman.

Committee on Transportation: W. B. Page, *Chairman;* Henry A. Vezin, S. Newhouse.

Committee on Hotel Arrangements: Robert Bunsen, *Chairman;* W. A. Bray, O. H. Hahn.

Wednesday was occupied in the trip from Denver to Leadville over the Denver and South Park Division of the Union Pacific Railway. A special train was furnished by the Railway Company. In the evening the third session was held in the Leadville City Hall.

In calling the meeting to order the President thanked the Local Committee for their efforts to make the stay of the Institute in Leadville pleasant and profitable, and then introduced Mr. S. F. Emmons, who delivered an address on The Geology of the Leadville District. Colored diagrams, illustrating the geological formations in the vicinity, were put into the hands of all the members.

A paper was then read by Mr. L. R. Grabill On the Peculiar Features of the Bassick Mine, which called forth discussion from Messrs. Clark, Rothwell, Ashburner, Howe, Raymond, and Maynard.

On Thursday morning the mines of Fryer Hill, Yankee Hill, Carbonate Hill, and Iron Hill, whose managers had kindly opened them to the inspection of the excursionists, were visited, and the party generously entertained at lunch by the different companies. The afternoon was enjoyably passed in a drive over the boulevard to Evergreen Lakes, five miles from Leadville.

At the evening session in the City Hall it was announced that the Council had decided to consider the Colorado meeting a consolidation of the spring and autumn meetings for this year, and that the dues of members and associates elected at the meeting would be $6 to February, 1883, the time of the next annual meeting.

Mr. J. C. Bayles then read a paper by Mr. John Birkinbine on Charcoal as a Fuel for Metallurgical Processes.

Mr. R. E. Chism read a paper on The Patio Process in San Dimas, Mexico.

Before adjournment, Mr. Percival Roberts, Jr., spoke warmly of the kind and generous treatment which the Institute had received at Leadville, and on his motion the thanks of the Institute were enthusiastically voted to its citizens, the managers of its mines, the gentlemen in charge of its smelting works, and the resident members of the Institute. Mr. R. Neilson Clark responded on behalf of the Local Committee.

Friday morning was spent in inspecting the following smelting works and mills: J. B. Grant & Co.'s Elgin Smelter, Cummings & Finn, Harrison Reduction Works, Tabor Mill, La Plata Smelter, and mills of the Leadville Gold and Silver Milling Companies, the American Mining and Smelting Company, and the Arkansas Valley Smelting Company. A visit was also made to California Gulch, to witness the process of gold washing there in progress.

The rooms of the Leadville Mining Club were opened to the members and guests of the Institute during their stay in Leadville.

PUEBLO EXCURSION.

Local Committee.

A. H. Danforth, *Chairman;* A. W. Geist, D. N. Jones, W. L. Graham, H. L. Wells, P. B. De Schweinitz, Ralph Crooker, 3d, Reese James, William Tatnall, L. J. Taylor, Joshua Crowther, R. W. Woodward.

At 1 P.M., on Friday, the party took a special train provided by the Denver and Rio Grande Railway Company for Pueblo, which was reached at 8 P.M. On Saturday morning the works of the Colorado Coal and Iron Company, at South Pueblo, were visited, after which lunch was provided by the company. A visit was then made to the Pueblo Smelting and Refining Company's works, and Manitou was reached at 7 P.M.

Sunday was spent in Manitou. Those of the party who chose made the ascent of Pike's Peak, visited the "Garden of the Gods," or inspected the "Cave of the Winds," to which the Institute had been kindly invited by the proprietors, Messrs. Rinehart and Snider.

VISIT TO EXPOSITION.

Exhibitors' Committee of Reception.

Thomas Manning, *Chairman;* C. C. Adams, George Fritch, John McKee, F. M. Hausling.

On Monday morning, leaving Manitou at 7 o'clock, the party arrived at the Denver National Mining and Industrial Exposition at 10 A.M. They were welcomed in a short address by Mr. C. C. Adams, and were afterwards entertained at lunch by the Committee of Reception; the balance of the day was spent at the Exposition.

In the evening the final session of the meeting was held in Assembly Hall, Denver University.

Dr. R. W. Raymond, Chairman of the Committee of the three Engineering Societies on a Holley Memorial, reported progress.

The President announced that the Council had decided to have the Institute take part in a joint session of the three Engineering Societies, to be held in New York City some time in November next, during the meeting of the Society of Mechanical Engineers, for the purpose of listening to an address on the Life and Life-work of Alexander L. Holley, to be delivered by Dr. R. W. Raymond.

Mr. Eustis read a paper on Comparison of Various Methods of Copper Analysis, which was discussed by Mr. Pearce.

The Secretary read a translation of a paper by Mons. Alexandre Pourcel, of Terrenoire, France, on The Relations of Carbon and Manganese in Iron and Steel.

Mr. A. Eilers read a paper by Mr. A. F. Schneider on High Percentage of Lime in Lead Shaft-furnace Slags, which was discussed by Messrs. Eilers, Pearce, Eustis, Raymond, and Rothwell.

The following papers were then read by title:

The Estimation of Mineral Oil in the Presence of Other Oils, by C. C. Hall, of Chicago, Ill.

The Practical Metallurgy of Titaniferous Ores, by William M. Bowron, of South Pittsburg, Tenn.

Notes on Some Reactions of Titanium, by Mrs. Ellen H. Richards, of Boston, Mass.

The White Path Gold Belt of Gilmer County, Ga., by H. C. Freeman, of Alto Pass, Ill.

The Treatment of Gold-bearing Arsenical Sulphurets, by R. P. Rothwell, of New York City.

Progress in Mining and Metallurgy, by Martin Coryell, of Lambertville, N. J.

The Anthracite Coal Beds of Pennsylvania, by C. A. Ashburner, of Philadelphia.

A Native Process of Smelting Copper Ores in the State of Jalisco, Mexico, by W. B. Devereux, of New York City.

On Silver Milling in Arizona, by W. L. Austin, of Charleston, Arizona.

Mr. David Williams then offered the following resolutions of thanks, which were seconded by Mr. James Park, Jr., in remarks expressive of the great pleasure which he and his fellow-members had expe-

rienced in this visit to Colorado, and the hope that the Institute might return in the future and find as great advance in all directions as the State has made in the past.

WHEREAS, The entertainment provided for the visiting members of the American Institute of Mining Engineers in Colorado, and the hospitality with which we have everywhere been received, have placed us under unprecedented obligations, and

WHEREAS, While we cannot but feel the inadequacy of such thanks as we can offer, and while we trust that our appreciation of the favors we have received will have opportunity to find expression in the hospitable entertainment of members visiting us in our respective homes, we still desire to place upon record a formal expression of our thanks, therefore, be it

Resolved, That our thanks are especially due to the Local Committee and Citizens' Committee at Denver for what they have done and are still to do for our convenience and pleasure; to the proprietors of the Windsor Hotel for the use of their Club-room; to the Denver Club for hospitality and courtesy; to the Union Pacific Railway Company for transportation to Argo, Golden, Central City, and Georgetown via the Colorado Central, and to Leadville via the Denver and South Park railroads; to the Local Committee at Central City for entertainment at the Teller House, and the use of their Opera House; to the mine and mill owners at Central, Black Hawk, and neighboring points; to the Local Committee at Georgetown for carriages and entertainment, and to the proprietors of the Terrible Mine; to Honorable T. B. Bryan and Colonel William Moore for entertainment at Idaho Springs; to the Local Committee and citizens at Leadville for carriages and courtesies and the use of the City Hall; to the mine and mill owners of Leadville for the privilege of inspecting their works, and for generous entertainment; to the Colorado Coal and Iron Company for showing their works and for entertainment, and to the Pueblo Smelting and Refining Company for the invitation to inspect their works; to Dr. William A. Bell and Mr. Thomas C. Parrish for courtesies rendered at Manitou in arranging for our accommodation; to the officers of the National Mining Exposition at Denver for free admission to the Exposition; to the Commissioners from the mining counties for the collation provided at the Exposition building; to the Boston and Colorado Smelting Company for courtesies extended at their works at Argo; to the citizens and owners of works at Golden, and to the Denver and Rio Grande Railroad Company for transportation from Leadville to Denver, and for the offer of reduced rates to several points of interest on the line of their road; and to Messrs. Rinehart and Snider for invitation to visit the Cave of the Winds at Manitou.

Resolved, That in tendering our thanks to those named, we feel that we have omitted many who might with propriety be included; and the Secretary is hereby instructed formally to thank, in the name of the Institute, all whose kindness has placed us under obligations.

Resolved, That while we congratulate our local members upon the brilliant success of their efforts to make this a memorable meeting of the Institute, we would say that we feel especial pride in claiming them as members, knowing that the high respect in which they are held by their fellow-citizens has given the Institute an added dignity and importance in the estimation of the people of Colorado.

Resolved, That we shall cherish the memory of this visit to Colorado as among the pleasantest and most profitable experiences of our lives, and that with the idea of natural wealth surpassing estimate, of enterprise almost exceeding belief, of

scenery which defies delineation or description, we shall always associate the remembrance of a hospitality, even more than these, unlike anything we have before known or experienced.

The resolutions were carried with applause.

The President in adjourning the meeting once more expressed the cordial thanks of the Institute to the people of Colorado, and said that he hoped and was convinced that the meeting would be of great profit both to the Institute and the State.

EXCURSIONS TO ARGO AND GOLDEN.

Local Committee at Golden.

Professor Albert C. Hale, *Chairman;* Mayor J. M. Morris, Professor Milton Moss, R. C. Wells, Hon. F. E. Everett, Hon. C. C. Welch, G. A. Duncan, Ed. O'Neill, Colonel P. R. Smith, R. Koenig, C. D. Peppard, J. C. Hodges, Jr., F. W. Clark, R. D. Hall, Rev. C. M. Jones, Rev. G. C. Rafter, Rev. T. L. Bellam, Rev. W. H. Williams, B. F. Snyder, A. A. Tuttle, J. A. McGee, A. G. Smith, C. Smith, George West, William G. Smith, John Nicholls, George Dollison, Al. Townsend, Mott Johnson, H. Todd, W. A. Dier, J. P. Boyd, C. H. Case, R. T. Covey, J. E. Benjamin, J. McLachlan, G. H. Kimball, Paul Lanius, J. G. Schall, Ed. Ullrich, C. Garbereno, Cecil Brown, Bert Everett, W. B. Evans, W. Gayton, Carlos Lake.

On Tuesday morning, at 10 A.M., an excursion was made, *via* Union Pacific Railway, to Argo and the Smelting Works of the Boston and Colorado Smelting Company, inspected under the guidance of Hon. N. P. Hill and Mr. Richard Pearce.

After lunch, provided by the company, the train proceeded to Golden, where the following works were open for inspection: Valley Smelting Works, Miners' Smelting and Reduction Company's Works, Golden Smelting Works, Brick Works of G. A. Duncan & Co., Golden Paper Mills, Cambria Tile and Brick Works, and the Golden Brick and Coal Company's Coal Mine.

A party was conducted through the Colorado State School of Mines by President Albert C. Hale.

A bountiful lunch was also served in the Court House, between 4 and 5 P.M.

In the evening the members of the Institute were invited to a banquet at the Windsor Hotel, given by the citizens of Denver, while the ladies of the party were tendered a reception in the hotel parlors.

The register, kept open during the whole of the meeting, but not, however, containing the names of all the members who joined the excursions for a time, or attended the sessions at points near their homes, bears the signatures of the following members and associates:

W. H. Adams,	Chicago, Ill.
A. A. Alexander,	Prescott, Arizona.
H. W. Armstrong,	Hulton, Pa.
C. A. Ashburner,	Philadelphia.
W. L. Austin,	Charleston, Arizona.
C. H. Baker,	Philadelphia.
R. D. Baker,	Philadelphia.
J. C. Bayles,	New York City.
Hermann Beeger,	Denver, Colorado.
Andrew M. Bell,	Denver, Colorado.
H. P. Bicknell,	South Pueblo, Colorado.
F. C. Blake,	Mansfield Valley, Pa.
A. J. Bowie, Jr.,	San Francisco, Cal.
V. M. Braschi,	New York City.
F. D. Browning,	New York City.
Charles P. Bryan,	Idaho Springs, Colorado.
S. M. Buck,	Coalburgh, West Virginia.
H. W. Bulkley,	New York City.
L. D. Bulkley,	New York City.
B. W. Cheever,	Ann Arbor, Mich.
Marshall Childs,	Pittsburgh, Pa.
Richard E. Chism,	San Dimas, Mexico.
Fred. W. Clark,	Alma, Colorado.
Joshua E. Clayton,	Salt Lake City, Utah.
Clarence K. Colvin,	Idaho Springs, Colorado.
Thomas P. Conant,	New York City.
George H. Cornell,	Youngstown, Ohio.
Torbert Coryell,	Lambertville, N. J.
W. E. C. Coxe,	Reading, Pa.
Ralph Crooker, 3d,	South Pueblo, Colorado.
D. R. Davidson,	Pittsburgh, Pa.
W. S. De Camp,	Lyon's Falls, N. Y.
P. B. De Schweinitz,	South Pueblo, Colorado.
F. P. Dewey,	Washington, D. C.
E. V. d'Invilliers,	Philadelphia.
W. J. Donaldson,	Emaus, Pa.
C. B. Dudley,	Altoona, Pa.
John Duncan,	Calumet, Mich.
A. Eilers,	Denver, Colorado.
G. D. Emerson,	Rolla, Mo.
S. F. Emmons,	Denver, Colorado.
George U. Engle,	El Moro, Colorado.
A. T. Enos,	Brooklyn, N. Y.
W. E. C. Eustis,	Boston, Mass.
J. W. Farquhar,	Easton, Pa.
E. M. Ferguson,	Pittsburgh, Pa.
Leon P. Feustman,	Philadelphia.
C. F. Findlay,	Chicago, Ill.
C. B. Finley,	Huntingdon, Pa.
J. J. Fisher,	Allentown, Pa.
J. P. Flynn,	Ashcroft, Colorado.

Emerson L. Foote,	St. Louis, Mo.
H. C. Freeman,	Alto Pass, Ill.
H. C. Frick,	Pittsburgh, Pa.
Henry Fulton,	Georgetown, Colorado.
Albin Garrett,	Philadelphia.
Frank W. Gibb,	Little Rock, Ark.
C. H. Gibson,	Freiberg, Saxony.
C. W. Goodale,	Charleston, Arizona.
L. R. Grabill,	Querida, Colorado.
J. D. Groesbeck,	Mapimi, Mexico.
Albert C. Hale,	Golden, Colorado.
C. C. Hall,	Chicago, Ill.
G. Hambach,	St. Louis, Mo.
A. W. Hare,	Kokomo, Colorado.
Fred. M. Hausling,	Tin Cup, Colorado.
F. J. Hearne,	Wheeling, West Virginia.
E. C. Hegeler,	La Salle, Ill.
E. L. Herndon,	St. Louis, Mo.
C. John Hexamer,	Philadelphia.
H. D. Hibbard,	Nashua, New Hampshire.
Thomas Hoatson,	Calumet, Michigan.
F. N. Holbrook,	Corralitos, Mexico.
L. Holbrook,	New York City.
George H. Holt,	Crested Butte, Colorado.
H. M. Howe,	Tucson, Arizona.
W. H. Hulick,	Easton, Pa.
Henry Janin,	San Francisco, Cal.
W. P. Jenney,	Salt Lake City, Utah.
E. P. Jennings,	Tombstone, Arizona.
D. N. Jones,	Bessemer, Colorado.
Maxwell Kinkead,	Altoona, Pa.
J. S. Lane,	Akron, Ohio.
R. F. Lord,	San Francisco, Cal.
W. S. McIntosh,	Pittsburgh, Pa.
Thomas Manning,	Denver, Colorado.
C. A. Martine,	Georgetown, Colorado.
F. A. Massie,	Charlottesville, Va.
J. A. Mathieu,	Detroit, Michigan.
G. W. Maynard,	New York City.
J. J. McDowell,	St. Louis, Mo.
Edwin Mickley,	Hokendauqua, Pa.
John J. Mickley,	Hokendauqua, Pa.
George C. Munson,	Milford, Conn.
James Nelson,	Youngstown, Ohio.
George Ormrod,	Emaus, Pa.
William R. Painter,	Carrollton, Mo.
James Park, Jr.,	Pittsburgh, Pa.
Richard Pearce,	Argo, Colorado.
John E. Pearson,	Denver, Colorado.
O. H. Pierson,	New York City.
W. H. Pettee,	Ann Arbor, Michigan.

W. F. Pinkham,	Nashua, New Hampshire.
F. Prince,	Audenried, Pa.
J. R. Rand,	New York City.
R. W. Raymond,	New York City.
Edward Reed,	Denver, Colorado.
Ross B. Reid,	Dunbar, Pa.
Ellen H. Richards,	Boston, Mass.
Percival Roberts, Jr.,	Philadelphia.
A. N. Rogers,	Central City, Colorado.
E. M. Rogers,	Central City, Colorado.
W. R. Roney,	Chicago, Ill.
W. W. Rose, Jr.,	Denver, Colorado.
R. P. Rothwell,	New York City.
S. Howland Russell,	New York City.
R. De Santa Maria,	New York City.
G. H. Sheldon,	Corralitos, Mexico.
Joseph A. Shinn,	Allegheny, Pa.
F. J. Slade,	Trenton, N. J.
J. Alden Smith,	Denver, Colorado.
L. X. Smith,	Colorado Springs, Colorado.
H. A. Stambaugh,	Youngstown, Ohio.
J. T. Stambaugh,	Youngstown, Ohio.
F J. Stanton,	Cheyenne, Wyoming.
W. N. Symington,	New York City.
D. H. Thomas,	Alburtis, Pa.
Edwin Thomas,	Catasauqua, Pa.
Samuel W. Thomé,	Philadelphia.
H. G. Torrey,	New York City.
L. C. Trent,	Denver, Colorado.
Pieter H. Van Diest,	Denver, Colorado.
F. W. A. Wahlberg,	Washington, D. C.
L. E. Warner,	Cincinnati, Ohio.
C. G. Weir,	New York City.
S. T. Wellman,	Cleveland, Ohio.
H. L. Wells,	Bessemer, Colorado.
David Williams,	New York City.
G. N. Williamson,	Irwin, Colorado.
N. R. Wilson,	Leadville, Colorado.
Walter W. Wishon,	Rolla, Mo.
H. R. Wolcott,	Denver, Colorado.
Fr. Mor-Wolff,	Berlin, Germany.
A. B. Wood,	Ann Arbor, Michigan.
R. W. Woodward,	Bessemer, Colorado.
C. P. Wurts,	New Haven, Conn.
James B. Young,	Pittsburgh, Pa.
Jesse B. Young,	Altoona, Pa.

PAPERS

OF THE

COLORADO MEETING.

AUGUST, 1882.

THE MINES AND MILLS OF GILPIN COUNTY, COLORADO.

BY A. N. ROGERS, CENTRAL CITY, COLORADO.

WITHIN a limited area of a few square miles around Central City there is a group of gold and silver bearing lodes whose brief history is too well known to call for present comment, but whose early prominence laid the foundation of a great and prosperous commonwealth.

In this group, 200 miles of vein length have been surveyed for government patent, and half as many more miles of discoveries appear of record as mineral locations, and are held as real property.

The extent and frequency of these lodes are due mainly to the structure of the rock which forms the mountains, the noticeable feature of which is its jointure; fitting it for the advent of fissures and the subsequent storing of mineral treasures therein.

The rock is of ancient origin but of recent upheaval. It is denominated metamorphic granite, and is of an age noted in other countries as being the mother of precious metals.

It has three lines of fracture everywhere observable, whether at the heart of the mountain or in the broken fragments at the mountain's base; first the bedding, and then two planes of cleavage, carving the rock into rhomboidal masses.

The principal cleavage traverses the country in a northeasterly and southwesterly direction, slicing the mountains into vertical sections; and this has shaped the course and occurrence of the veins.

The cleavage is not local, but general, and the agency which has produced it has held to its course as persistent as the magnet, with a power not less manifest than the force which has uplifted the mountains to their present position. From this it may be assumed that the fissures are not the result of local accident, but of a widespread and prevailing force, operating without practical limit, and thus assuring their continuance in depth beyond the reach of human devices for working.

While the lodes mainly lack the development which is requisite

to entitle them to consideration as mines, not a few have been worked to sufficient depth to prove their continuity and to determine much respecting their characteristics.

It may be said that not much has been discovered to distinguish them from the same order of veins in other countries, or other sections of this country; the most remarkable feature respecting them being, without doubt, their grouping and frequency of occurrence. This, it may be conjectured, has been due more to the forces which have made the fissures than to the agencies subsequently employed to fill them. No attempt will be made to account for the infilling of the mineral matter, nor to compare the observed facts, as we find them in working, with the suggested theories of vein-formation. It will suffice, for the purpose of this paper, to state briefly the information which has been gathered in our working experience, so far as the same may have a bearing upon this obscure subject.

The veins, though similar in character, are exceedingly diverse in features, which are seldom the same in those of near vicinity and close relation. There are individualities belonging to nearly every lode as marked as the features of the human face—among which may be noted a differing matrix; a different combination and complexion of minerals; a difference in hardness; characteristic crystallizations; jointure, selvage, etc.;—all minor features, plainly distinguishable and interesting as a study, but difficult to understand.

It is not less difficult to determine why we should have a central group of gold lodes, approximately within a radius of 1½ miles, which is circumscribed by a margin of silver lodes, extending beyond to a greater distance; all of them occurring in analogous fissures, and in a "country" presenting no perceptible difference in its physical characteristics.

It is stated that there is evidence of difference in age in some of the veins. If this is based upon any distinctive characteristic of the vein-filling, it will doubtless lead to the conviction that we have a numerous family, the members of which have come with frequency, since there are so many differences to account for; and this is hardly compatible with the apparent quiet of the country since the veins were formed.

Among the facts observed at the depth now attained, it may be especially noted:

(1.) That the country rock shows a well-defined stratification which mainly declines to the east.

(2.) That the cleavage crosses the strata with a nearly vertical dip,

but with modifications of underlie, both to the north and south, seldom becoming flatter than 60° from the horizontal.

(3.) That the veins invariably follow the cleavage, and the cleavage invades all the rock except the veins themselves, which as a rule have a laminated structure, the joints or laminæ taking the line of the vein and lying parallel with its walls.

(4.) That the zones of "pay" are apparently independent of depth or the influence of strata-belts of the country, and are mostly accidental in position and direction, though they are sometimes influenced by cross jointure of the "country" and by secondary veins, which follow out for a distance on them.

(5.) That the occurrence of eruptive rock along or in the vicinity of veins does not sensibly change their character, increase their value, or determine their tendency to either of the precious metals. Porphyry occurs, alike by the side of a rich or a poor lode, alongside a gold or a silver vein, and in rare cases as a dike between two veins with differing features.

(6.) That porphyry has its cleavage in common with the country rock, and the cleavage, being older than the veins, proves that the porphyry itself is likewise of greater age. Therefore its occurrence is not liable to break, intercept, or fault the veins. This is also true of dikes of other intrusive rock which have the common cleavage of the country.

(7.) That cleavage is always present in this vicinity, except in the veins. It never crosses them in their normal condition, and this determines their junior age. Being thus the last incident of construction, the veins must be as stable as the mountains themselves. Indeed, few if any faults have been discovered, in the progress of mining, up to the present time.

(8.) That the cleavage planes are less frequent as the rock is more crystalline; but the fracture is more perfect, the faces smoother, and the walls of a vein more true with crystalline than with schistose rock.

(9.) That the lines of fracture are as well defined at the lowest workings of the deepest mine, as at the surface. Hence, nothing is indicated by experience unfavorable to the belief in the continuity of the fissures in depth. The inclosing rock being of an age that cannot change in depth, and the fissures being likely to continue with its jointure, the life of the vein would appear to depend upon the stability of the filling matter.

Bearing upon this point, it has been observed that the vein-matter

is analogous in all the veins, though it exists in almost endless variety as to its universal combinations and the association of the precious metal therewith. One lode may carry its value in copper, another in iron, the next in blende, the fourth, perhaps, in gangue or in galena.

The matrix is composed chiefly of feldspathic quartz, differing in texture, complexion, and in every essential feature, from the inclosing rock. It is not, as a rule, if indeed in any case, banded, after the ribbon combination, whereby a progressive structure, from the walls to the centre, is traceable. Fine pyritous mineral matter is usually disseminated to some extent through the whole of the gangue, with masses, seams, and strings of the various minerals, characteristic of the vein, interjected; sometimes upon one wall, sometimes upon the opposite wall, and again in the middle of the vein, but always with the tendency to jointure along the course of the fissure. The vugs and cavities, containing crystals, are mostly in the interior of the vein, with lengthened axes parallel with its walls.

There is no apparent evidence of heat having been present during the process of infilling, the "country" showing no perceptible change with nearness to the vein. It is the same in appearance at a distance of one inch as at ten feet from the inclosing wall.

This briefly comprises the salient points of this group of lodes, which, it must be admitted, have been in the main poorly handled. The chief mistakes have grown out of the erroneous conception which the pioneers had concerning their value, and what was necessary to mine them properly. The titles were taken in 100-foot claims, and not unfrequently stock companies, with inflated capital, were organized upon fractions of these. Thus, failure from the start was inevitable, and became the rule, after the waste of much time and money. The pernicious effects of the 100-foot system have never been fully overcome to the present day, and the proper combinations of property for successful working have rarely yet been attained.

The mining is mostly done by the ordinary system of shafts, levels, and back stopes, and this class of work is done here with as much economy of labor as in any other section of the country. In some instances it may be claimed that the facilities for handling ore are superior to the average methods used elsewhere.

Most of the gold ore is reduced by stamping, and is amalgamated, both inside and outside of the batteries, after which blanketings are caught, to be panned, or returned to the batteries and put through

a second time with the coarse rock. Below the blankets, suitable sluices and buddles are used to collect and concentrate the outflowing tailings, which, being reduced to a 10-per cent. gangue limit, become a marketable product for smelting, because of their fluxing qualities more than their value. The richer sulphurets are hand-picked and cobbed for the smelters, and some grades of ore which are not free-milling, are concentrated and likewise sold; but the sands, or separating gangue, are then treated under stamps, after the manner of ordinary mill rock.

The milling practice here is somewhat different from the methods employed on the Pacific slope. This has led to much unfavorable comment respecting the construction of our mills and the mode of operating them. It is claimed that the millmen of this section are slow, bound to old prejudices, and that the mills do neither good work nor much of it. This is a grave charge, which, having received the sanction of high authority, claims attention at this time, because of the opportunity furnished for a candid discussion of the subject. If the methods here employed are defective and wasteful, they ought to be abandoned, and the experience of others, if well founded, should be taken. It is of too serious moment, however, for hasty and inconsiderate action. While the customs of this section have been tenaciously adhered to in the face of adverse criticism, it has not been from lack of understanding the points at issue, but from convictions, based upon long experience, that the practice of other sections is not applicable to the circumstances of this. It is held that the milling ores of this district combine a larger percentage of sulphurets than those of the Pacific slope, and that the sulphurets are as a rule less valuable. In order to mill to any high percentage of the contained value, very fine crushing and good battery amalgamation are essential. This, the underlying proposition, followed out, has, after the usual changes, mishaps, and waste of money in experimenting, built up the present stamp-mill system, which is but little modified from an ancient custom, except in the matter of better construction and more attention to detail.

Fine crushing and battery amalgamation involve the necessity for holding the ore in the mortar until the work is thoroughly done, and this occasions all the points of difference between the mills of the two sections. The one has a shallow mortar, short drop, coarse screen, and fast motion; the other, a deep mortar, long drop, fine screen, and slow motion, the very opposite in principle and construction, and with the very opposite aim in view; the one, to effect

quick discharge and fast crushing; the other, to hold the pulp in the battery until its contents have become thoroughly reduced and a high percentage of its value taken out. That each may do its work properly, and with the best economy, should be easily conceived, if not frankly admitted; but to contrast, in units, the ore crushed per stamp in the two cases, as the basis of comparison between the efficiency of the mills, would be to misjudge the case entirely. Without considering the relative hardness of the rock to be crushed, the quality of the work done will be as the cube of its fineness, and this, in the two cases (if I am properly informed as to the California practice), will be as one to eight; that is to say, the California mill works to a 40-mesh screen, and the Colorado mill to an 80-mesh; the one reducing each cubic inch to 64,000 divisions, and the other to 512,000 divisions. The only authentic data at hand, from any California mill, by which a comparison may be made in respect to the fineness of crushing, is taken from a chapter of Raymond's Report for 1872, written by Mr. G. F. Deetken, of Grass Valley, in which he gives an elaborate and excellent description of the mills of that section. Relative to the matter of crushing, he says: "The object being to liberate fine particles of metallic gold, disseminated through the quartz, so that they can be collected and subsequently amalgamated, a fine crushing is always desired. . . . . . The fineness of crushing is found to be as follows; the battery sands, crushed through a number six slot screen, contain an average of:

"1. Slimes which remain suspended after three minutes' rest in still water, 19 per cent.

"2. Slimes passing through a sieve of 6400 holes per square inch (No. 1 excluded), 51 per cent.

"3. Sands passing through 1600 holes per square inch (excluding Nos. 1 and 2), 23 per cent.

"4. Sands not passing through 1600 holes per square inch, 7 per cent."

This, by computation, would give, approximately, 468,000 particles to the cubic inch, and, doubtless, represents the finest crushing practice in that vicinity, as he states that "it is the work of one of the best mills in California." A test of the fineness of pulp from the Bobtail mill of this place was made two years ago, on a ten days' run of one battery, which gave a computed result of not less than 700,000 particles to the solid inch, as follows:

Caught on a 40-mesh sieve,	1.17	per cent.
" " 60 "	17.55	"
" " 80 "	13.08	"
" " 100 "	10.33	"
Passed through a 100-mesh sieve,	57.87	"
Total,	100	" .

From this it will be seen that no proper comparison of stamp work can be made without considering its quality, and the question is not what the mills will accomplish in the disposal of the rock, but whether it be expedient to reduce the same to the degree of fineness which is here practised. This evidently depends upon the manner in which the gold is held in the rock; and respecting this it may be assumed that little is definitely and satisfactorily known. It is here believed to be very finely disseminated through the mass, as a rule, but there will be, no doubt, great diversity of opinion respecting the matter. Very recently, Mr. Melville Attwood, F.G.S., in a paper on the subject of "The Microscope in Metallurgy," published in the *Mining and Scientific Press,* June 24, 1882, made the following remarks:

"The greatest error, however, in our milling for gold, is, I believe, the fine stamping of medium-grade vein-stone. As I have stated before, stamping ought to be conducted, like the cracking of a nut, if possible, to break the enveloping shell and to free without injury the metallic kernel. . . . The screens in general use here reduce the pulp so fine that 80 per cent. of it will pass through a sieve having 2500 holes to the square inch. Fine films of gold like those I exhibited at a former meeting, which were mechanically mixed with the iron pyrites, and the laminated gold, formed by unnecessary dead stamping, present so much more surface in proportion to their weight that they are carried away by slightly moving water, and easily dissolved by some of the so-called chemicals used in the pan process.

"I have mounted on slides specimens of the Grass Valley (No. 5) and Bodie (No. 6) golds, the former as broken from the hard vein-stone, and the latter the same as it is generally met with in the richer portions of the Bodie veins, occurring comparatively loose in a quartzose ferruginous matter, the larger portion of the quartz being in rounded grains (No. 7), and the gold mostly crystallized (No. 8). You will see by examination of the specimens brought for inspection, how great the loss would be in reducing it with a flow of water fine enough to pass through a sieve having 2500 holes to the inch, or having a diameter of one-seventieth of an inch.

"In amalgamation in the batteries, unnecessary dead stamping causes some of the amalgam to be battered and converted into a black mass, becoming mixed with the baser mineral, particularly so, should a small quantity of zinc get into the mercury, the magnetites and waste iron from the wear of the shoes, etc., would be coated with mercury; and the amalgam thus sickened, a large portion of it will pass over the silvered plates. (No. 10, sample from one of the Bodie mills.) I find the battery pulp, even without mercury in the batteries, but when a large proportion of pyritic matter is being treated, to have a decided acid reaction, due in a great measure to the presence of ferric and ferrous salts, soluble in water. The former of these salts destroys the action of the quicksilver, enfilming it with a compound insoluble in water, and preventing that metallic contact taking place between detached mercurial globules so necessary to amalgamation."

We are not prepared to differ with Mr. Attwood as to the result of his observations on the ore he examined, nor to question the correctness of his judgment as to the best method of treating it. If his statements are well founded in respect to the California ores, and if it be likewise true that the mills on the Pacific slope are planned for that kind of work, then we can say, with a great degree of confidence, that they would be but poorly adapted for the milling of Colorado ores. As against the result of Mr. Attwood's investigations, I will state some facts, which have been gathered here, tending to show the manner of association of gold with the rock of this section. I have a small quantity of gold which was taken, as amalgam, from the copper tables of a mill in my charge for the purpose of examining its features and fineness. The amalgam was gathered and the quicksilver was dissolved out with acid, which left the gold, it is assumed, in substantially the same condition, as to its particles, as when it was taken from the tables. If they were bruised, beaten, and laminated, these features would be shown under the microscope, as in the case reported by Mr. Attwood. Ninety-two per cent. of this gold was passed through a 100-mesh screen. It must therefore have exceeded in fineness 10,000 divisions to the square inch, and 1,000,000 particles to the cubic inch. A sample of this, under a microscope with a power of 600 diameters, does not show any flattening of the particles, but a granular structure, with the appearance of crystalline formation, tending to clusters. The gold and quartz, in some instances, were found still wedded to each other in bonds so intimate as to defy both stamps and quicksilver.

In one case, a prism of quartz had its surface dotted with granules about the tenth of its diameter in size, each covering $\frac{1}{100}$ of its exposed surface, thus forming, approximately, $\frac{1}{1000}$ of its mass. By computation this would give it the bulk of $\frac{1}{1,000,000,000}$ of an inch, more or less, solid measure. In the light of this revelation, it may not be claimed that the Gilpin County mills are doing too much work upon the ore by dead stamping. Rugged as the stamp-mill may appear, as a machine it has to do with a most delicate problem, and, if we are to believe the senses, must work to a degree of fineness almost beyond human comprehension. The question, how this may be best attained, presents itself for consideration. The practical methods of this section have been the outgrowth of experience, finally resulting in the mills as we see them to-day, differing so widely from the California mills as to be the subject of adverse criticism. The point of departure between the practice of the two sections commences with the seeming necessity for fine crushing to amalgamate the ores of this section, which, from the statement of Mr. Attwood, must differ widely from California ores. If we concede the necessity for fine crushing here, which is not expedient in the treatment of California ores, then we may account for what seems to be the best practice in each case, though it differs widely. Here, the doctrine of fine crushing is the underlying principle, and the methods of accomplishing the work are believed to be well founded and judiciously carried out. The stamp-battery, as a reducing device, has stood the test of many generations, and is believed to be without a rival for economy, and for fineness and uniformity of work, which may be graded to any degree of attenuation sought. A battery which would be best adapted to reduce to forty divisions cannot be expected to attain to the fineness of eighty divisions to the linear inch, merely by changing the size of the screen; it requires something more—a water dam to keep the disintegrated rock "*in chancery*," away from the screen, until the work upon it is completed; hence the deep mortar and high issue in the mill designed for fine crushing. This departure from the fast-crushing battery of the Pacific slope is the direct cause of the other changes, which follow in logical sequence. A high water level in the battery is inevitably followed by the long drop of the stamp, and this, again, by a less number of drops in a given time, to do the same work or to develop the same number of foot-pounds, which is its expression. The effective duty of a properly-constructed stamp-battery should be accurately measured by the foot-pounds developed by the falling stamp—

the product of the weight, drop, and speed, which are three elements of mechanical work. It is claimed, however, that this is not in accordance with observed results. In a recent paper by Professor Monroe* (read at the Lake Superior meeting of the Institute, August, 1880), this subject has been elaborately discussed, mostly from data published in the reports of Dr. Raymond, as Commissioner of Mining Statistics. In introducing the subject, Professor Monroe quotes from Dr. Raymond as follows:

"In considering the economical application of stamping machinery, we meet, at the beginning, with serious difficulties in obtaining accurate data for comparison. The weight and fall of stamps vary as the shoes and dies wear out; and this may lead to a change of speed also. Again, the capacity of stamp-mills is directly dependent, in some degree, upon the nature and extent of discharge, fineness of screens, and other peculiarities of the battery. Finally, the hardness and tenacity of the rock crushed varies so much that comparisons between different localities cannot be implicitly trusted."

And in giving the conclusions of Dr. Raymond, he says:

"Dr. Raymond then gives a number of tables comparing a large number of stamp-mills in Colorado and California, giving the weight, fall, and speed of the stamps, and the tons crushed per horse-power developed, and concludes the paper with arguments in favor of high speed for stamp batteries."

Professor Monroe then takes up the subject, extending the investigation to embrace the steam stamps of the Lake Superior copper region, and determines "that both the increase of the weight of the stamps and the increase of the height of the lift tend to diminish the amount of ore crushed per foot-pound, and that if it be necessary to increase the crushing effect of the battery, it is better and more economical to increase the weight of the stamp than the height of the drop. This law does not, apparently, apply to velocity of impact, for the atmospheric stamp and the Ball stamp have a final velocity equal to that of a two-foot drop and a six-foot drop respectively; these stamps, however, would seem to give better results than the drop stamps with but eleven inches fall," and closes his paper with:

"1st. The product of a stamp-battery, other things being equal, is directly proportional to the foot-pounds developed in the fall of the stamp, and to the number of blows per minute, provided only that

* *Transactions*, ix., 84.

the discharging capacity of the battery be equal to or greater than its crushing capacity.

"2d. Both the force of each blow and the number of blows per minute may apparently be increased indefinitely, with but slight diminution of the rock crushed per horse-power, provided that the discharge be increased in the same proportion.

"3d. The discharge of a battery depends on the character of the screen (its area, the size and number of its openings, etc.), and on the number and duration of the splashes produced by the fall of the stamp. The discharge cannot, therefore, be increased indefinitely, but to a certain extent increases with the speed of the battery or with the number of drops per minute.

"4th. With a limited discharge, equal to or less than the crushing capacity of the battery, the product may be raised by increasing the speed, but cannot be raised by increasing the force of the blow.

"5th. A light stamp with a high drop and a heavy stamp with a low drop produce nearly equal crushing effect, provided that the foot-pounds developed are the same. The advantage, however, is in favor of the heavy stamp and low drop.

"6th. To increase the crushing effect of a stamp-battery it is better to increase the weight of the stamps than the height of the drop.

"7th. A drop of 8 inches has been generally adopted as giving better results than higher drops. It is possible that still lower drops may prove economical.

"8th. The objection to high drops does not seem to apply to high velocity of impact as obtained by spring stamps, atmospheric stamps, or steam stamps, which apparently give results as good as, or even better than, those from stamps of which the foot-pounds are due principally to weight.

"9th. High speed and high velocity of impact lessen the weight of the stamps and diminish the number of batteries requisite for a given amount of work, and, therefore, lessen the first cost of the plant. These smaller batteries do not demand large buildings for their accommodation, nor the construction of large and expensive foundations. To offset this saving must be placed the extra wear and tear due to high speeds.

"10th. In the ordinary construction of stamp-batteries with cams and tappets, velocity of impact can be secured only by giving the stamps a high lift. This is incompatible with high speed. But as we have already shown, under the conditions of limited discharge, speed is more to be desired than high velocity of impact.

"11th. With steam stamps, atmospheric stamps, or spring stamps, both high velocity of impact and high speed can be secured. By the use of machines of this character the maximum effect can be obtained with the smallest plant. The product that can be obtained from one head will be limited by mechanical conditions, and by the impossibility of increasing the discharge beyond a certain limit. The last limitation will operate sooner with fine screens than with coarse.

"12th. In fine stamping both the difficulty of discharge and the work of crushing increase with the fineness of the product."

These conclusions seem to be unfavorable to the efficiency of Colorado mills, and are different from what would be expected by those familiar with their work. Yet they are supported by seemingly convincing testimony, all tending to the same verdict. It is admitted, however, that the data are not strictly reliable, since, as stated, "The capacity of stamp-mills is directly dependent in some degree upon the nature and extent of discharge, fineness of screens, and other peculiarities of the battery; and finally, the hardness and tenacity of the rock crushed varies so much that comparisons between the different localities cannot be implicitly trusted." Very naturally, comparisons can only be made with safety when the conditions are the same. In this case, the comparisons cannot be "implicitly trusted," and it will appear that they cannot be justly made. To say nothing of the character of the rock, varying, perhaps, widely in hardness and tenacity, no discrimination is made respecting the quality of the work done upon it, which might vary still more, since the screens may vary from thirty to eighty meshes to the linear inch, not an unusual variation, according as the amalgamation is done inside or outside the battery. There is a margin for doubt here, which will more than account for the seeming paradox, that the law of the velocity of impact is effective in the case of the steam stamp, but not in that of the drop stamp. Recurring to the previous statements respecting the relative fineness of the tailings of the Bobtail and Grass Valley mills, it will be observed that they are as 700,000 to 468,000, or as 3 to 2. If it be assumed that the work expended to attain this fineness is in the same ratio, then the Bobtail mill has done one and one-half times as much work on the rock as the other mill, if the quality of the rock be the same in both cases. The Bobtail mill has 500-pound stamps, dropping 16 inches thirty times per minute; thus developing, per stamp, nearly 29,000,000 foot-pounds in twenty-four hours to crush one ton of rock. The Grass

Valley mill has 700-pound stamps, dropping 10 inches, and sixty-eight times per minute, thus developing, per stamp, 57,120,000 foot-pounds in twenty-four hours to crush $1\frac{6}{10}$ tons of rocks, or, at the rate of 35,700,000 foot-pounds per ton of rock crushed. If the ore should be held in the batteries until reduced to the Bobtail standard of fineness, one and one-half times as much work, or 53,550,000 foot-pounds per ton of ore would be absorbed. This indicates an efficiency of 54 per cent. as compared with the Bobtail mill. This apparent difference is too large to be taken without question of doubt, though the data seem to be strictly reliable. The proof goes far enough, however, to show the fallacy of indiscriminate comparisons.

It is more than probable that, if a close comparison were made, taking into consideration the quality of the work as well as the quantity, it would appear that the foot-pound of power expended would render its equivalent in duty under any circumstances; and that, in every instance, where the apparent advantage is in favor of the short drop, it is due to coarser crushing, naturally resulting from the low issue and quick, if not premature, discharge of the pulp from the battery. We must reason that when a stamp is raised through a certain distance there is a definite amount of energy stored in its mass which will be given out in its fall. If it is not expended upon the rock which takes the blow, what becomes of it? If it goes into the foundation or is wasted in any manner, by undue shocks and jars of the machine, its effects will at once be made manifest, and become visible in wear and waste. It is a living force, which cannot be taken out of the stamp without being put into something else, leaving its mark. It has been stated that it may be lost in "heat or packing," which, though vague, is evidently intended to mean that the blow has been given without its equivalent effect. If heat is the result of a blow, the blow has done its work, either upon the rock or upon the metal. If upon the metal, the metal will show its effects. It may be claimed, therefore, that the destruction of metal, per unit of work, will be inversely as the efficiency of the battery. In other words, the work expended in blows cannot be lost, and will have its normal effect upon the rock, or will occasion an abnormal wear of the metal surrounding it.

The proportionate waste of metal, then, should be an infallible test as to whether the power is properly expended.

The data at hand respecting this are limited to the working experience of two mills—those which have already been mentioned—the Grass Valley mill of California, and the Bobtail mill of Central City.

These are taken to be representative mills of the two sections, and the only mills furnishing available data for comparison at this time. The proportionate wear of metal, per unit of work and per ton of ore crushed, will be shown by the appended table:

	Bobtail Mill.	Grass Valley Mill.	G. V. Mill reduced to Bobtail standard of fineness.
Work Delivered by Stamp.			
In millions of ft.-lbs. per lb. of shoe worn,	20.000	31.733	
In millions of ft.-lbs. per lb. of die worn,	92.900	59.500	
In millions of ft.-lbs. per stem broken,	720,000.000	30,844.800	
Metal Worn.			
From shoe per ton of rock crushed,	1.44 lbs.	1.125 lbs.	1.8 lbs.
From die per ton of rock crushed,	0.31 lbs.	0.6 lbs.	0.9 lbs.
Quantity of Rock.			
Crushed by shoe without removal,	70.8 tons.	79 tons.	53 tons.
Crushed by die without removal,	578. tons.	100 tons.	67 tons.
Crushed by stem before breaking,	25,000 tons.	864 tons.	576 tons.

It will appear, by inspection of the foregoing: 1st. That the Grass Valley mill wears out the most metal per ton of rock, and has the greatest proportion of wear on the die. 2d. That the Bobtail mill performs one and one-half times the work to each pound of metal worn from the die, and twenty-three times the work to the breakage of a stem, as the other mill. 3d. That the shoe of the Bobtail mill wastes four and six-tenth times as fast as the die, thus proving that the blow is taken by the rock and not passed through the rock to the die beneath. 4th. That while the Bobtail wears the shoe four and six-tenth times as fast as the die, the other mill wears its shoe but twice as fast as the die, which indicates that more of the work passes through the rock into the die, employing the same as an anvil. 5th. That the relative endurance of the stems in the two cases must be taken as the most conclusive evidence that the blow of the Bobtail stamp, notwithstanding the velocity of the impact, due to a greater drop, has been absorbed in the rock, and the stem has not received the violent shock which would result from falling upon the metal of the die. 6th. That by careful analysis of these data, no undue wear can be detected in the battery or foundations of a long-drop mill, as compared with that of a short drop, and

therefore its work must have been properly expended upon the rc in the battery. In marked contrast to this, and pertinent to 1 subject, I will quote the remarks of Mr. J. M. Adams, of Sil City, Idaho (in a chapter entitled "Hints on the Washoe Proces which will be found in Raymond's Report for 1873). In describi his practice with a stamp-mill, Mr. Adams says: "Low feeding the best; let iron *almost* wear on iron; under this system a stem m break occasionally, but it does not take long to put in another. Ev if three stems out of twenty are broken every month, the cost of pairing amounts to little compared with the increased producti obtained by low feeding. The stem almost invariably breaks in c place, namely, where it comes out of the stamp-socket or boss. T broken surface of the wrought-iron stem shows the iron to be th oughly crystallized; its fibrous condition having been destroyed the constant jar." This statement is presumed to represent fai the effects of iron "*almost* wearing on iron," and is given here wit out comment as pertinent to the discussion, and as an experie remote from our own practice.

Much stress has been laid upon the loss occasioned by the sta working in the battery water. Its retarding effect cannot be an i portant element in the discussion, but, being easily disposed of, seems proper to consider what may be its influence upon the crus ing duty of the stamp. Its effect will vary as the depth of the wat and will be greater in a deep mortar than in a shallow one. V will assume the outside limit in a high-drop mill to be about o foot of water, through which the stamp is expected to drop in doi its work. If the stamp has a diameter of 8 inches its section will about $\frac{35}{100}$ of a square foot, and the water displaced by its fall w be $\frac{35}{100}$ of a cubic foot, which, if it be considered as water alo will weigh 21.7 pounds. Taking into account the solid matter he in suspension, it may be well to call it 25 pounds. Now this d placement has commenced at the surface, where the pressure is ze and has continued, with the pressure increasing in direct ratio w the depth, until the final pressure upon the bottom of the stamp 25 pounds; the total resistance, therefore, expressed in units work, will be 25 pounds $\times$ 1 foot $\div$ 2, or, $12\frac{1}{2}$ foot-pounds. If t weight of the stamp be 500 pounds and the drop 16 inches, wh falling freely it will develop a blow of 667 foot-pounds, but, meeti a resistance during its fall of $12\frac{1}{2}$ foot-pounds, the effect will diminished about $1\frac{9}{10}$ per cent., which, if lost, is not of serious mome But it is not lost, since the reactive buoyancy of the fluid assists

lifting the stamp, and the same amount is recovered, except the trifling friction due to a wave motion of the water, which is needed for other purposes. Again, the effect of fine screens has been claimed to be another source of loss, which interferes with the duty of the stamp. If the screen, by impeding the discharge, can affect the duty in the sense of absorbing any portion of the work, being of thin sheet iron, punched through with many slots, it would be battered to pieces in an hour; and yet the screens require changing but once in six weeks, after having discharged about 4000 tons of battery slime through a single screen. The resistance to the outflow of the pulp, due to the screen, should be quite accurately measured by the pressure of water behind. Since this does not average, in head, more than half its width, or some five inches above its bottom, it is too small for serious consideration. If the loss be supposed to occur from reworking the battery pulp after it is reduced to the requisite fineness for discharge, the reply will be that the rate of discharge may be increased by adding water to thin the pulp, and to raise the pressure behind the screen, thus increasing its outflow.

Whatever may be the effect of the deep mortar and fine screen, it is apparent that they have been intelligently chosen to retard the outflow from the battery; and any attempt to hasten the work by discharging more freely will defeat the purpose in view. Not unfrequently, by unskilful management, stamp-batteries are run with a very considerable loss in efficiency, but this loss is due to quite a different cause. When a mill "pounds," as the expression goes, by which is meant that the stamp falls through the pulp upon the die, it is certain that its work is wasted. In this case it will probably be found that one end of the battery is empty and the other end banked with the surplus of dirt; part of the stamps will be going through to the bare metal and the others stopping at half-stroke on the accumulated pile, without making an impression upon it.

In this perplexing condition no work will be accomplished, and not unlikely stems will be breaking at the rate of one or two a day. The experienced millman will remedy the difficulty by lengthening the drop, in order to give chance for the settlement of the stuff, under the pounding-stamps. The short drop, causing undue commotion in the battery, has prevented the settlement of sands, and the stamp has gone through to the die, churning the dirt to the other end of the mortar, where it has banked and shortened the play of the fellow stamps; resulting in loss of work, injury to the mill, and defeat of amalgamation. These are the evils which have attended

every attempt to shorten the drop and quicken the motion of mills with a deep mortar and high issue. It has been tried so often, with the same results, that this point has been settled beyond question.

If the excessive work (in foot-pounds of power expended), which is shown to be done by the mills of this section, is not wasted in useless destruction of metal,—of which we have no evidence,—then it must go into honest blows upon the rock, and the question is narrowed to the consideration as to whether this is needless, in order to free the gold for proper amalgamation. In this connection it is pertinent to remark that the custom of regrinding and amalgamating in pans, and other kindred devices, is preached and practised in connection with the California mills, and in other sections where the quick drop and low issue are used. This is a fair admission that more work is needed upon the quartz than is given by the stamps of such mills. What, then, is the advantage of multiplying machines and processes if as good work may be done in the battery? It is not because of cheapness, for it is patent that the stamp, as a pulverizer, is far superior to the muller, both in the quantity and quality of the work it will do with a given power and given wear of metal. It is not because the pan is superior as an amalgamator, for it has many defects not common to the battery, while the battery has no defects not common to the pan.

The gold taken in the battery is the "bird in hand," and battery amalgamation is the ratchet-wheel, in milling, which holds to what you get. If 75 per cent. of the gold, which a good mill will save, can be caught in the battery without other attention than is given by the feeder, why should it be permitted to escape for the purpose of making a race for its recovery, with a multiplication of expensive devices beyond? All of these may be used later, in case they can be made to pay.

If so large a percentage may be saved in the battery, the conditions favoring amalgamation are too valuable to be neglected. If neglected, it must be for the reason that the advantages are too poorly understood to be appreciated. The working of the battery would seem to be that both the gold, upon being released from its matrix, and the mercury, which is fed into the battery, tend to gravitate through the shifting sands to the bottom of the battery box. Here, beneath the mass, they are continuously manipulated by the blows and pressure of the stamps. Freed from the earthy matter and mineral contaminations which float off from above, the surfaces of the gold become brightened by attrition of the sands, and the mer-

cury, with lively affinity, readily unites with each particle thereof, forming amalgam.

It is difficult to conceive of circumstances more auspicious for their union. Thenceforth they journey together. While either by itself could have passed the screen openings, and been lost, now united they can no longer run the gauntlet, but must find a lodgement on the battery coppers. The depth of the mortar and high-water line evidently perform important functions in preventing their escape, until they have had ample opportunity to unite; thus rendering their escape more difficult. This is conceived to be the ordinary happening with the coarse gold.

It is observed that the gold taken from the outside coppers is exceedingly fine, compared with that from the inside coppers. From this it is apparent that the fine gold is carried with the water currents through the screens before it can be placed in bondage, after the manner described. We reason, therefore, that by quickening the drop of the stamp, the greater commotion of the battery water and the stronger currents, which would be due to a shallow mortar and low screen, would aid this escape and be prejudicial to battery amalgamation. The combination, then, of the deep mortar, long drop, and slow motion, considered in respect to the purpose in view, is not chosen by caprice and upheld without reason; it is that most likely to secure the desideratum sought, namely, to extract directly and during the crushing as high a percentage of the value as possible, giving but subordinate attention to any further treatment of the pulp. To accomplish this, the battery is chosen for the work, because:

It takes the place of more complicated and more expensive devices.

It is direct and continuous in its work.

It grades the material closely, pulverizing finely, evenly, and cheaply, discharging the waste as soon as it is disengaged, thus ridding the amalgamation of a hindrance and the mill of an incumbrance.

It delivers its power in blows, which take advantage of the brittleness of the rock, crushing one fragment upon another with the least friction and abrasion of the metal.

It grinds the sands and gold by pressure and attrition of the shifting mass, rather than by rubbing and abrasion of metals, thus avoiding evils incident to the latter, among which may be named chemical reactions of the metals set free, flouring of the quicksilver,

abrasion of the gold, and the interference of slimes, which absorb, waste, and sicken the mercury, rendering it sluggish in its affinities.

The arguments against battery amalgamation seem to be limited to the claim that it interferes with the crushing efficiency of the battery.

Dr. Raymond, in discussing the subject in his Report for 1870, says: "To obtain the best results, stamp batteries should be built and run to secure the highest efficiency and economy in crushing only, without reference to amalgamation. The amalgamating apparatus should be adapted to the batteries, not the latter to the former. If interior plates are employed, they should not be expected to catch the greater part of the gold, nor should the pulp, escaping through the screens, be swiftly and carelessly manipulated, when a little extra space and time devoted to it, almost without extra labor, would avoid much loss." By extra space and time is evidently meant the substitution of regrinding machinery and the pan process, which involves additional work on the ore after it has passed the battery. The comparison, then, between the work of the two mills should cover the whole work put upon the ore, in order to be just and intelligible. Among other objections which have been urged, the following is by J. M. Adams, of Silver City, Idaho, in the paper before mentioned. It will be understood that Mr. Adams is speaking of the treatment of auriferous silver ores. He says: "But there is a strong objection to amalgamation in the battery. The amalgam thus formed is mostly a gold amalgam, and hence it is worth much more than the ordinary amalgam of a silver mill, and of this the workmen are all aware. It is, therefore, an additional temptation to stealing. The only benefit to be claimed for it is the possible catching of some of the gold otherwise floating away in the water. But, on the other hand, it is not practicable to use quicksilver without a mechanical loss; and the quicksilver being more or less charged with gold, the loss of such as is not gathered and united involves more or less gold. Every casting, such as a shoe or die, in the battery is full of flaws and blow-holes. Hard gold amalgam collects in these, and, in spite of the most careful picking and breaking, every shoe and die, when used up and thrown away, contains a considerable amount of gold amalgam." This is quoted in part to show, by Mr. Adams's testimony, the proneness of gold to stay in the battery where mercury is present, which is an excellent reason for seizing the opportunity to take it while willing.

The loss of quicksilver, spoken of by Mr. Adams, is an item which it is highly important to consider, though the data for comparison between mills of this and other sections are not at hand. This loss has been claimed to be excessive in the battery, but it is thought to be far less than by pan amalgamation, and that statements heretofore made respecting the matter must have been erroneous, or else the milling must have improved very much in later years. In Mr. J. D. Hague's Report, in 1868, it was spoken of as being from $\frac{1}{10}$ to $\frac{1}{20}$ of a pound of mercury to the ton of rock. In 1870, Mr. Reichmacher of this place, in a well-written article, copied into Raymond's Report, claimed the loss in the battery to be three times as much as is again recovered in the amalgam. The actual average loss in the Bobtail mill, in crushing 125,000 tons of rock, amounted to less than $\frac{2}{100}$ of a pound to one ton of ore—strictly 1 pound to 56 tons of rock crushed—and this covers the entire loss in and about the mill. So much time has been given to discussing the points of difference in the milling practice of the two sections, that it is considered injudicious to prolong this paper to embrace what would otherwise be of interest respecting the mechanical details of construction of the mills, and the itemized cost of treating ores therein.

The remaining and most important topic which claims attention, is the gold-saving qualities of the mills, or the percentage of value utilized.

This will be given in the appended statement by Mr. George H. Gray, assayer and metallurgist, to which your attention is invited, for information in detail.

A brief synopsis of the working results, as shown by this statement, is as follows:

Of upward of 2000 tons of ore, which were weighed, sampled, and assayed, before treatment in the Bobtail mill, the saving, by amalgamation above the blankets, was fully 70 per cent. of the contained value of gold in the ore, and about 6 per cent. of the silver, of which latter the ore contained but $1\frac{3}{8}$ ounces per ton. The milling was done at an average cost of but little more than one dollar per ton, embracing all items of current expense, repairs, and removals of the plant, but not covering interest on its cost.

While disclaiming any intention to criticise the milling practice elsewhere, or to invite a controversy in respect to any claimed superiority of our own methods, it has been thought that a full and fair

understanding of these methods, the reasons for adhering to them, and the results obtained therefrom, has been wanting, in order to give a fair impression of what the Gilpin County mills are doing, and that a more complete account of the same would be of interest on this occasion.

STATEMENT PREPARED BY MR. G. H. GRAY.

CENTRAL, August 19th, 1882.

A. N. ROGERS, ESQ., SUPT. CON. BOBTAIL MINING COMPANY.

DEAR SIR: At your request I have looked up the experiments conducted in your mill during the years 1876–77, 1878, and 1881, and submit the following:

The object of the experiments during the first three years was to ascertain, as accurately as possible, the efficiency of the mill in saving the gold from the crude ores. No pains or expense was spared to make the tests thorough and complete. From 50 to 60-ton samples were weighed in 500-pound lots, from which two shovelfuls were taken as a sample. The whole sample thus obtained weighed about 500 pounds; this was crushed to the size of peas, well mixed, sampled down by quartering, then pulverized and assayed. A sample of the pulp was taken from above the blankets and below the tables. Every fifteen minutes during the twenty-four hours a large bowl of pulp was caught, care being taken not to allow the vessel to overflow, thereby hindering any concentration of the ore; this was dried, sampled as above, and assayed. These samples aggregated between 2000 and 3000 tons, and are supposed to be a fair average of the ore treated during the given time. The actual results from these tests, upon weighed ore, show an average saving of 70 per cent. of the gold and 6 per cent. of the silver above the blankets. The average value of silver from the repeated tests has been found to be only $1\frac{38}{100}$ ounces per ton of crude ore. Since the gold thus saved does not cover the blanket gold and what still remains in the concentrates, in order to arrive at the total efficiency of the mill these must be added.

In the annexed tables the tons are estimated from the recorded cords crushed, allowing $6\frac{1}{2}$ tons to the cord, which is a low estimate. The gold caught per assay will be *short* the gold in the blanket tailings, whereas the returns from the United States Mint will be *long* that amount. In all of the tables the gold remaining in the concentrates is not given, as they become a marketable product to smelters, and their value is accounted for outside of the mill; if added, however, the total per cent. of gold saved would be about 80. The silver has been purposely omitted, as we claim no saving. The year 1881 was devoted to ascertaining the efficiency of the mill in the treatment of blanket tailings. These were weighed, sampled, and assayed, as already described, mixed in certain proportions (which will be given in the tables) with wall rock or poor ore, the same being also weighed, sampled, and assayed.

The following represents the work done by the mill for the year 1876, last seven months of 1877, and 1878, and also three tests on blanket tailings.

Very respectfully yours,

G. H. GRAY.

SUMMARY FOR 1876.

Number of tons of ore treated (as per books),	20,962.50
Ounces of gold in ore (as per assay), (0.64 oz. per ton),	13,416.00
Ounces of gold in tailings (as per assay), (0.152 oz. per ton),	3,186.30
Ounces of gold caught (as per assay), (0.488 oz. per ton),	10,229.70
Ounces of gold returned by U. S. Mint (as per books),	10,187.55
Percentage of saving by direct amalgamation,	$75\frac{93}{100}$
Tons of mineral contained in ore by assay,	2,162.244
Tons of mineral concentrated and sold,	981.263
Percentage of mineral saved,	$45\frac{38}{100}$

SUMMARY FOR LAST SEVEN MONTHS OF 1877.

Number of tons of ore treated (as per books),	13,472.875
Ounces of gold in ore (as per assay), (0.799 oz. per ton),	10,764.82
Ounces of gold in tailings (as per assay), (0.243 oz. per ton),	3,273.90
Ounces of gold caught (as per assay), (0.556 oz. per ton),	7,490.92
Ounces of gold returned by U. S. Mint (as per books),	7,428.63
Percentage of saving by direct amalgamation,	69
Tons of mineral contained in ore by assay,	1,387.700
Tons of mineral concentrated and sold,	769.044
Percentage of mineral saved,	$55\frac{40}{100}$

SUMMARY FOR 1878.

Number of tons of ore treated (as per books),	22,936.00
Ounces of gold in ore (as per assay), (0.642 oz. per ton),	14,724.90
Ounces of gold in tailings (as per assay), (0.154 oz. per ton),	3,532.14
Ounces of gold caught (as per assay), (0.488 oz. per ton),	11,192.76
Ounces of gold returned by U. S. Mint (as per books),	11,167.17
Percentage of saving by direct amalgamation,	$75\frac{80}{100}$
Tons of mineral contained in ore by assay,	2,543.600
Tons of mineral concentrated and sold,	1,499.680
Percentage of mineral saved,	$58\frac{96}{100}$

BLANKET TAILING TEST.

These tailings are caught by placing a California blanket on an inclined way or strake, directly below the tables. The blankets are taken up, washed, and replaced every thirty minutes. The sands and minerals thus collected are restamped, mixed with wall rock. The following is the result of three tests, silver being omitted for reasons already given:

Test No. 1.

Character of ore.	Amount in tons.	Assay gold, oz.
Blanket tailings,	11.081	0.78
Wall rock,	31.012	0.11
Above mixed,	42.093	0.283
Pulp from mill,		0.11
Saved by direct amalgamation,		0.173
42.093 × 0.173 gives ounces gold caught,		7.28
United States Mint returns (as per books),		6.99 oz.
Percentage of saving,		61

Test No. 2.

Character of ore.	Amount in tons.	Assay gold, oz.
Blanket tailings,	12.150	0.83
Wall rock,	35.000	0.09
Above mixed,	47.150	0.28
Pulp from mill,		0.12
Saved by direct amalgamation,		0.16
47.150 × 0.16 gives ounces gold caught,		7.54
United States Mint returns (as per books),		7.47 oz.
Percentage of saving,		56

Test No. 3.

Character of ore.	Amount in tons.	Assay gold, oz.
Blanket tailings,	12.150	0.80
Wall rock,	34.000	0.09
Above mixed,	46.150	0.276
Pulp from mill,		0.106
Saved by direct amalgamation,		0.170
46.150 × 0.170 gives ounces gold caught,		7.84
United States Mint returns (as per books),		7.69 oz.
Percentage of saving,		60

DISCUSSION.

Dr. R. W. Raymond, New York City: Mr. Rogers, in the paper which has just been read, has made several allusions to the first discussion of this question among American engineers, which I think I had the honor to make. I certainly did reach conclusions which were unfavorable to the practice then prevailing in Colorado as to the speed of stamps. Reichenecker's paper, in one of the early volumes of my reports, furnished the best account of Colorado practice that could then be obtained, and one which I think for that time was accurate and trustworthy; and subsequently, I persuaded Mr. Deetken to give me a similar account of the practice in Grass Valley, California, which I think still remains the best authority extant upon that subject. Professor Monroe has still further augmented these data, and treated them with greater mathematical accuracy in the paper referred to by Mr. Rogers.

It is manifestly impossible to take up in detail the statements of the elaborate paper which has just been read. I wish only to say one or two things very briefly; but before I say anything in reference to the answer which Mr. Rogers makes to the criticisms which

I made, or which he infers that I made, on the Colorado practice, I wish to express my very great gratitude to him for adding another and most valuable paper to the series which our *Transactions* and some of the government reports and technical periodicals contain on this important question. We are very much indebted to every man who will take the pains to record his results and express them in so admirable a manner as has been done in this paper.

I wish, however, to say with regard to the part which my name bears in that paper, that when I made the comparisons from the data of a large number of stamp-mills in this country out of which certain inferences were made not altogether favorable to the Colorado practice, I did not come to my conclusions solely by comparing the effective work of stamp-mills in any one locality and the effective work of stamp-mills in a different locality—a distant locality—and one in which the conditions were altogether different. It is true that I made a general comparison of that kind, but I had the advantage, at least, of observing cases in which the stamps were running on the same ores, in the same district, and at the same time. In Nevada I found slow stamps and rapid stamps side by side, in Colorado I found slow stamps and rapid stamps side by side, and my favorable conclusions concerning the rapid running of stamps, in reference, as I confess, chiefly to the aggregate amount of rock put through, were often drawn from mills in districts where all the conditions were tolerably similar with the single exception of speed, and, as a consequence, these conditions were eliminated in each locality in the comparisons which I first made.

Secondly, when I went through Colorado and studied the practice against which my early criticisms were directed, and against which I contended with some earnestness, urging progress in the direction of more rapid running of machinery, it was not a speed of 30 drops per minute, which Mr. Rogers now calls slow, that I chiefly condemned; it was 15 or 18 per minute that I saw, and that I criticised. In those early days I could count the stamps in many a Colorado mill, as I rode by it, hearing the fall of every separate stamp in the mill. It is true that the average even then was, according to Mr. Hague's partial list of mills, but a little less than 30 drops per minute, or according to Mr. Reichenecker's paper, 22 to 28 per minute. But I found mills in process of construction, intended to run at much slower speed, and millmen who earnestly advocated slow running. When I went further west, and found speeds which were

rapid, even for that time, in some cases as high as 90, I naturally thought 15 a little conservative.* Now I call attention to the fact that Mr. Rogers has got from 30 drops per minute much better results than would be got from 15, and, in view of this, I think I may claim to have contributed in an humble way to a great public benefaction.

I am deeply impressed by the arguments in this paper. It is difficult to dispute or even to question its facts. When a man gets up and tells his story so well, we feel not only as if it must be true, but as if it must be universally true. But I suppose Mr. Rogers himself will admit that, before this question is ultimately settled, other mills should be watched and their results should be as carefully recorded as his have been. And perhaps I may draw from his paper a suggestion, namely, that other mills may have to be built to treat the extremes of rapid running. It is not safe to experiment on fast running in mills made to run slow, nor *vice versa;* so that possibly, after all, the question cannot be settled without further modifications of the existing conditions. Nevertheless this paper is a proof that the work here has not been done ignorantly and out of a blind and positive belief in slow running. Yet it is a strange phenomenon that at the same time elsewhere in the country the tendency has been very decidedly in the other direction. Some of the best mills in the country—those run with the greatest economy—are running over a hundred drops per minute, and the tendency is to enlarge even that number.

Still, the question whether it would be better to separate the amalgamation from the crushing, so as to get the greatest possible work out of the crushing machine, remains. If the necessity for battery amalgamation is the only reason why you crush less per unit of power, or per unit of fixed capital and general expense and labor, there is room for a discussion, in which I do not now undertake to engage.

I wish again to express my thanks to Mr. Rogers for this valuable paper.

Mr. George W. Maynard, New York City: I wish to add my

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* Since making these remarks, I have refreshed my memory, as to the statements in my paper on "The Speed and Effectiveness of Stamps" (*Transactions of American Institute of Mining Engineers*, vol. i, p. 40), and have modified slightly the remarks in consequence. I wish, also, to add that, although it was the slowest running mills in Colorado which attracted my attention most strongly to the subject, I did, undoubtedly, think the average of, say, 30 drops, too slow for economy. Possibly, that may not be the case, if economy is measured by the work done for horse-power developed; but there are still other elements of economy. R. W. R.

humble tribute to this admirable paper of Colonel Rogers. As many of you are aware, I came to this country in the early days, and have taken a very active interest in the treatment of the ores, and I started out, I must say, with the notion that all the ores ought to be concentrated before amalgamation. I know now that I was wrong in taking that view, and I believe that the true course is to stamp, amalgamate (as is being done), and then concentrate the tailings. Now comes up a more important question than that of speed, and that is whether the gold that we do save in the mill is all free gold, and whether we would save it by quicker working; that is to say, by putting a larger quantity through a coarser mesh screen, and then concentrating what passes through the screen. I should like to see that worked out in greater detail.

Secondly, I should like to ask Colonel Rogers what the percentage of sulphurets is in the tailings, as they are concentrated at present by the crude methods here used.

And thirdly, what the average percentage of gold and silver is found to be in the concentrated tailings, and also what quantity of tailings can be concentrated in twenty-four hours, or in a shift, and what the cost is. I believe that the present method of treating the tailings is a crude method. We have before us the excellent results that are obtained in Germany with the admirable Rittinger buddles and the shaking table, which treat very fine slimes, and clean them in a most marvellous manner. Then, too, there is the Frue vanner, which I find giving very excellent results in Grass Valley, California.

Mr. Rogers: Professor Maynard asks for the percentage of sulphurets in the ore. I cannot give the percentage for other mines, but I can state that in the Bobtail, which is rather poor in mineral, the saving is six per cent. of the amount in the ore, and the value of these concentrates will run from half an ounce to an ounce of gold per ton.

President Rothwell, New York City: I wish to say to the members of the Institute that I heartily agree with the speakers who have preceded me that this paper which you have just heard is a most valuable one, and I hope that other members will take up the subject and carry it on.

The question of what drop of stamps is best adapted to the ore, whether the speeds and drops are just as they should be or not, neither Mr. Rogers nor anyone else can take to be settled, but we have here at least a starting-point for investigating that question and for settling it hereafter.

I am not quite sure whether the practice of amalgamating in the battery on ores which are as rich in sulphurets as these are might not be supplanted by roasting and chlorination. The condition of the ore would be rather improved by the roasting, and the chlorination would obtain a very much higher percentage of gold from the ore itself. Whether the cost of roasting and chlorination here would be too great to allow it to be practised on these ores I am not prepared to say, for I have not the data from which to judge. I do know that the cost is not so great as is generally supposed. I have been practising it myself under conditions that were more economical than these, but with ores that were scarcely higher in gold, and the percentage which we have obtained from roasted arsenical sulphurets has been as much as 90 per cent. Whether the difference in the percentage which might be obtained here would pay, and more than pay, for the additional cost of chlorination, is a question I am not able to solve, but I suggest its solution to others who are in the practice.

Mr. Richard Pearce, Argo, Colorado: I would like to say one word with reference to the use of the chlorination process on the Gilpin County ores. I do not believe that the ore that goes to the stamp-mill here has as much gold in it, or anything like as much, as the ore the President has referred to. The ore in Gilpin County will not average more than from three to five-tenths of an ounce per ton, and any attempt to extract that gold by a system of chlorination, I think would be a failure here when we consider the expense of the necessary plant at the present time. With regard to the concentrated tailings, my experience is that here, too, there are a great many difficulties connected with the use of the process. I refer to the Plattner process, for I have had no experience with the Mears process of chlorination under pressure.

President Rothwell: Of course, I would not pretend to controvert the views of Mr. Pearce. I have had no experience with these particular ores, and there is nothing but experience which gives the means of judging; but with regard to the chlorination of the whole mass of the ore, as it comes from the mines, I do not think that could be considered. My suggestion is that the ore, as it comes from the mines, might be concentrated, and then the process of roasting and chlorination be possibly applied with advantage to the concentrates.

HIGH PERCENTAGE OF LIME IN LEAD SHAFT-FURNACE SLAGS.

BY ALBERT F. SCHNEIDER, E.M., C.E., GERMANIA, UTAH.

The peculiar conditions under which lead and silver ores are now smelted in Salt Lake Valley, Utah, render it advantageous to make slags that are siliceous and carry a high percentage of lime.

The ores treated come from Utah, Idaho, Montana, and Nevada; nine-tenths coming from Utah. These ores are siliceous, and contain but little fluxing material; the iron present scarcely sufficing for the sulphur and arsenic. Formerly ores high in iron were furnished from Cottonwood Cañons, but this supply is meagre. The ores from Idaho, Montana, and Nevada are high grade galenas, more or less impure. They generally require a large amount of iron for the sulphur, arsenic, and antimony.

In the winter and spring of 1880–'81, we were treating at the Germania Works principally Bingham Cañon lead ores and silver ores from Tintic. The former contained 15 to 30 per cent. silica, and only 4 to 5 per cent. iron (generally as iron pyrites); they ranged high in lead and low in silver, and carried more or less alumina; the lead was present chiefly as carbonate. The silver ores from Tintic contained sulphides, and ran as high as 80 per cent. silica.

We had been running on a slag approximating 40 per cent. FeO, 20 per cent. CaO, 10 per cent. other bases, and 30 per cent. SiO_2, which had heretofore been very satisfactory; but with the class of ores then coming in it was of the utmost advantage to use less iron and more lime, especially as the iron ore (50–55 per cent. iron and 5–7 per cent. silica) cost four times as much as the limestone (50–55 per cent. lime, 3–5 per cent. silica). The large amount of alumina in the slag influenced them for the worse; the addition of lime to the charge helped them, and after many experiments regarding the proportion of FeO, CaO, and SiO_2, a slag approximating 35 per cent. FeO, 25 per cent. CaO, 5 per cent. other bases, and 35 per cent. SiO_2 seemed to answer

our purpose; the percentage of alumina had a marked effect upon the silica in the slag.

As I was called East about this time, the matter was further pursued by my assistant, Mr. T. S. Austin, who, while cleaning up some scrap iron that had accumulated at the works, made a slag of the following composition: 27 per cent. FeO, 28 per cent. CaO, 8 per cent. Al_2O_3, and 34 per cent. SiO_2. This he concluded was slightly too acid and too rich in lime, thinking 30 per cent. FeO, 28 per cent. CaO, 33 per cent. SiO_2 would work better; which was made the basis for further trials when I returned from the East. The furnaces were then run on slags ranging in composition from 24 to 28 per cent. CaO, 30 to 36 per cent. FeO, 32 to 35 per cent. SiO_2, 5 to 10 per cent. Al_2O_3; but for some ores the proportion of lime seemed still too small, and the slags not acid enough. So, starting with 30 per cent. CaO, 30 per cent. FeO, 35 per cent. SiO_2, and changing to 28 FeO, 30 CaO, 36 SiO_2, we settled at last on the proportion of 3 FeO, 3 CaO, 4 SiO_2; but with slags ranging from 7 to 12 per cent. Al_2O_3 and 2 to 4 per cent. other bases (besides FeO and CaO), the slags were a little too acid for the amount of FeO present, so that the formula had to be continually modified accordingly. As a general rule the increase in alumina called for an increase in the proportion of lime; hence a slag with 24 per cent. FeO, 30 per cent. CaO, 34 per cent. SiO_2, and 10 per cent. Al_2O_3 ran very well.

A trial was made of carrying twice as much lime as protoxide of iron in a slag made from ores containing considerable alumina. The trial was too short to give any definite results, and when the slag was analyzed it only showed 35 per cent. CaO, and 21 per cent. FeO; the furnace remained open and hot during the experiment.

Many details as well as fractions of percentages have been omitted in this sketch, as they would not alter the principle. Though the slags varied greatly in the percentages of CaO, FeO, Al_2O_3, and SiO_2, yet the ratios between these were quite fixed and approximate certain types. When normal, the slags approximating the proportion of 7 FeO, 7 SiO_2, 5 CaO, and 1 to 1.5 Al_2O_3, and those approximately 4 SiO_2, 3 FeO, 3 CaO, and 1 Al_2O_3, are clean as regards silver and lead, and keep the furnace open and hot. The former drive a little faster, and both use but little more fuel than those high in iron. These slags have a smooth, oily flow, and even when considerable matte is present make but little splutter as they run into the slag pots. They have a distinct crystallization,—the first mentioned, short rhombic prisms; the latter, rhombohedrons.

The crystals are black with a greenish tinge, glassy, well defined, apparently built up; a depression being frequently seen on the plane faces. Any excess or lack in the principal constituents of the slag changes the crystallization in a marked degree, ranging from what might be called pectolitic and stringy to fine granular non-crystalline, with many gradations between. The presence of alumina has a marked tendency to decrease the percentage of silica and iron and to raise that of lime, so that latterly the slags have approximated 35 to 36 per cent. SiO_2, 25 to 27 per cent. FeO, 26 to 28 per cent. CaO, 10 per cent. Al_2O_3 (with only 2 to 3 per cent. Al_2O_3 the slags have run up to 39 per cent. SiO_2).

Metallurgically the slags are as good as they are commercially for Utah; as stated, they contain little or no lead and silver when normal; (in practice about 0.3 per cent. lead, and 0.25 oz. silver per ton, when making 100 oz. bullion.) The furnaces run well, keep hot and open, and the matte and speiss separate completely. Though using a little more fuel than the more fusible slags containing more iron, the advantage of carrying more ore and a less costly flux in the charge makes them more economical. I have been informed that Mr. August Rath, the efficient superintendent of the Horn Silver Smelting Works, has been and is running his furnaces very successfully on siliceous slags very high in lime. The ores treated are siliceous, containing much sulphate of lead, free sulphur, and antimony.

There is one peculiarity about the matte that is made with these slags,—it averages as low or even lower in lead, but higher in silver, than that made with slag containing more iron and less lime. The amount of matte made with these slags is less than that made with slags high in iron. Taking this latter fact into account with the fact that these slags as a general thing come down practically short in lime, notwithstanding the most careful analyses of ores and fluxes, the almost inevitable conclusion is that sulphide of calcium is formed, and goes into the slag. The slags, when analyzed, show an excess of lime, though practically the lime is wanting; this excess is apparently due to the sulphide of calcium. The speiss made with these slags seems normal. All kinds of ores, from impure sulphides to pure carbonates, are now treated with these slags.

It might be well to call attention again to the important part played by alumina. In an abnormal slag made some years ago the SiO_2 was only 20 per cent., Al_2O_3 15 per cent., CaO 25 per cent., FeO 36 per cent., and yet the slag ran well and was apparently acid to the eye. Similar shortages in silica were noted in presence of much

alumina, but not to so great an extent. The furnace remained hot and open. The almost invariable shortage in silica in presence of large amounts of alumina, and the needed addition of lime, seem to point, perhaps feebly, to the conclusion, that alumina under certain conditions acts as an acid in slags.

The furnaces were generally run on coke and charcoal, sometimes on coke alone; they are too low for the best working of these slags, being only 11½ feet from the tuyeres to the charging doors. The furnaces of small cross-sections in the crucible worked poorly. In a furnace of large section, lately built, these slags worked best; and, should the furnaces be made considerably higher (or hot blast be used), there seems to be no reason why even a higher percentage of silica and lime should not be used in lead shaft furnaces.

Since the above was written, slags running over 40 per cent. SiO_2, with considerably less FeO than any of the slags mentioned, have been made to work successfully.

Discussion.

Mr. Richard Pearce, Argo, Col.: If I had known that the subject of slags was to be introduced this evening, I might have come prepared with a few notes on reverberatory slags. In Montana, where silver copper ores are smelted in reverberatory furnaces, the oxides of manganese are used as a flux for the silica in the ores, in lieu of lime or oxide of iron. The outcrops of the veins in the Butte district consist largely of the minerals pyrolusite and psilomelane. The oxide of manganese plays two parts; it acts as a flux for the silica, and also as an oxidizing agent on zincblende, which is present in the ore in large quantities. The slag produced is of a very peculiar character. According to the results of an analysis made some six or eight months ago, it contained 30 per cent. MnO, 12½ per cent. ZnO, and 48 per cent. SiO_2. It gelatinizes both in strong and in weak hydrochloric acid. The slag was very fluid, and, when rapidly cooled, it had the appearance of obsidian. Slow cooling gave it a green appearance such as is sometimes seen in lime slags.

In this connection there is one other point of interest: the copper matte obtained, which contained from 50 to 60 per cent. of copper, was found also to contain as much as 3 per cent. of sulphide of manganese. The occurrence of sulphide of manganese in copper matte

is certainly rare; this is the first time it has ever come under my notice. It possibly plays the part of preventing too great a loss of copper in the slag, for, while manganese exists in the matte, the copper is less liable to oxidation.

Mr. W. E. C. Eustis, Boston, Mass.: Mr. Schneider mentioned one point that interested me,—the capacity the lime seems to have of absorbing sulphur. I have noticed the same thing in copper smelting. The phenomena observed were as follows: we were in the habit of crushing our copper matte fine, calcining in a furnace, grouting with lime, and putting this mixture, with sufficient silica, into a small blast-furnace, where it was smelted. The resulting product was about two-thirds copper and one-third blue metal. For some reason, which I do not recollect, the lime was omitted, while the other circumstances remained substantially the same; the resulting product, however, was a very little copper and a great deal of matte, thus proving conclusively, to our satisfaction, that the lime absorbed the sulphur from the imperfectly oxidized sulphides of copper, and allowed the copper to run into metal.

It then occurred to us that we might make a saving by adding the lime in the shape of carbonate (limestone) to the mixture in the furnace, while calcining; but we were disappointed entirely in the results. The resulting product from the blast-furnace was as bad as in the case where no lime was used. The reason for this is probably somewhat as follows: carbonate of lime loses its carbonic acid very soon after it gets into the calciner, turning into oxide, while the matte retains the most of its sulphur, and then the lime absorbs its quantum of sulphur before it leaves the furnace; it is then useless for grouting purposes, the mixture made from it has no adhesiveness, and there is no oxide present to react on the last atoms of sulphur in the matte.

Dr. R. W. Raymond, New York City: In the Lehigh Valley region very high percentages of lime are carried in blast-furnaces making gray foundry pig; sometimes more lime is charged than iron is taken out. This is for the double purpose of making a less fusible slag, thus assuring a high temperature in the hearth, and of removing sulphur (as calcium sulphide in the cinder), the presence of which seems always to prevent the open grain in otherwise "gray" iron. There is also a relation, somewhat obscure, between sulphur and silicon in the pig.

President Rothwell, New York City: The presence of sulphide of calcium in slags is a matter of interest to those who are

using mineral wool, for, when much of it is present in the slag from which the wool is made, the wool will act injuriously upon steam pipes, etc. Its presence may frequently be detected by the strong odor of the sulphuretted hydrogen evolved.

Dr. Raymond: A simple test for determining whether sulphide of calcium is present in a mineral wool is to dip the wool into ordinary ink; if the sulphide is present, a strong odor of sulphuretted hydrogen will be perceived.

THE PATIO PROCESS IN SAN DIMAS, MEXICO.

BY RICHARD E. CHISM, SAN DIMAS, DURANGO, MEXICO.

San Dimas, in the State of Durango, Mexico, on the frontier of the State of Sinaloa, is the centre of an extensive and rich mining region, which has been exploited for over a hundred years; and the patio process for working silver ores has there attained the highest perfection of which it is capable. Local modifications have been engrafted upon the underlying principles of the process, but, as a whole, the San Dimas practice so fully illustrates its typical capabilities, that I have undertaken to describe its workings in the hope of lightening, to some degree, the labors of my professional brethren who may have occasion to visit Mexico.*

As is tolerably well known, the patio process, like all other systems of free amalgamation, is not successful with ores containing more than a trace of zinc or lead, the presence of zincblende being especially obnoxious. Iron and copper in small quantities are not particularly disadvantageous. The process succeeds very well with all sulphide ores which do not contain much more than a trace of arsenic and antimony, provided the tailings are concentrated, although, of course, it is best adapted for free milling ores. For suitable silver ores that contain small amounts of free gold the process is still a good one, but where the gold is combined with sulphurets, a considerable and even an excessive loss is inevitable. Hitherto the Mexicans have submitted to this loss, but, since the introduction of American mills, they are gradually abandoning the patio process in favor of the other.

The San Dimas ores have a gangue of quartz and feldspar. They are composed principally of silver sulphides, with some chloride and

* Mexico is the second silver-producing country in the world, and it is safe to say that from three-fourths to seven-eighths of the product comes from the patio mills.

some native silver, and they carry considerable gold. The impurities are copper pyrites, copper and iron pyrites, and, frequently, traces of zinc, antimony, and arsenic. The ores are cobbed and hand-picked at the mines, and come down to the *hacienda* sorted into four classes, in pieces whose size varies from that of an egg to that of an orange.

The four classes into which the ores are sorted are:

1. First class, for exportation (*metal de primera clase*, or *metal de exportacion*). These ores should be worth, in gold and silver, $400 a ton, and upwards. It is selected by the eye, and it is in masses of pure ore without quartz veins. In Spanish such ore is called *metal hecho*, "made ore."

2. Second class, for working on the patio (*metal de beneficio*). This is worth from $60 to $400 a ton. It contains the same minerals as the ore of the first class, but with more gangue. Quartz is called by the miners *guija*, and ore with much quartz is called *guijoso*. Feldspar is called *caliche*, and feldspathic ores are called *metal calichoso*. An ore with much gangue is called *despoblado*. *Quemazon* is a black, porous kind of decomposed ore that looks like cinders. The first and second class ores of the size above indicated are called *metal gabarro;* smalls, or fine ore, are called *metal granza*.

3. Third class (*metal granza de llunque*, or *tierras de llunque*). This class comprises the smalls from the cleaners, and is of variable value, according to that of the first and second class ores.

4. Fourth class (*metal granza de labores*, or *tierras de labor*). This comprises the smalls from the workings in the mine. Being generally mixed with considerable dirt it is inferior in value to any of the other classes.

On arriving at the hacienda, the large ore, *gabarro*, is broken up to the average size of large peas, though some pieces may be as large as hazelnuts. This breaking is done either by hand (at a cost of $2.66 a ton), or, in some haciendas, by rude stamps with wooden stems and iron shoes, the total weight of each stamp being about 300 pounds. These stamps are usually set in batteries of four or five, and are moved by a water-wheel. At the hacienda of which I had charge, a Blake crusher has lately been introduced to do this work. The crusher is to be run by a belt from a spoon arrastre (*tahona**), and it is expected that the cost of crushing will be reduced to thirty cents a ton. The cost of crushing by stamps is at least seventy-five cents a ton. It is also expected that the product of the crusher will

* Pronounced *towna*.

be much finer than can be readily obtained by hand or by Mexican stamps. This will leave less grinding to be done afterwards, and thus will increase the product of the hacienda.

The crushed ore is charged into the tahona, an arrastre run by water-power acting on a ring set with wooden spoons, which is, in fact, a horizontal water-wheel. (Plate II.) The largest tahonas in San Dimas have the central cup (*tasa*), where the grinding goes on, 3 m. in diameter and 0.5 m. deep. The diameter of the spoon ring is 6 m., and that of the circle touching the exterior extremity of the spoons is 6.64 m. These tahonas are intended to hold 1500 pounds of crushed ore, which they grind down to slimes in about three days. According to calculation the water used should develop, at ordinary times, about four horse-power, of which it is quite probable that not more than one-quarter is utilized. The grinding-stones, when new, weigh from 1200 to 1500 pounds; when worn down to about 400 pounds they are removed. Two new stones are never put in at the same time; an old one and a new one are always working together. From one-half to two-thirds of the charge is put into the tahona at starting, together with a few ounces of quicksilver to catch the fine gold, and just water enough fairly to wet the charge. As the grinding proceeds, the rest of the charge and more water are added, until, when the grinding is ended, the contents of the tahona are in the form of a liquid sand.

The tahona is made to revolve very slowly at first, but when the charge is well reduced in size its velocity is increased, the rule being to run fast enough to keep the heavier parts of the charge from settling down and clogging the stones, and not so fast as to make the mud splash out centrifugally. The proper speed is usually from seven to ten turns a minute. When the bottom stones of the tahona are newly laid (*retajado*), it is necessary before grinding good ore to work up a few *cargas** of the lowest class of ore (*tierras de labor*) in order to fill up the cracks between the stones and prevent the escape of gold amalgam derived from the richer ores. The progress of the grinding is tested from time to time by taking an assay (*tentadura*) on a small red earthen plate (*platillo*) from a point half way to the bottom of the cup. When no grit can be perceived between the fingers the grinding is regarded as complete. Horny-handed Mexicans, conscious of a want of sensibility in their fingers, try for grit by rubbing the assay on the lobe of the ear.

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* A Mexican *carga* is 300 pounds.

The average time of grinding a charge, which I alluded to above as three days, is generally shortened a little if the man in charge of the grinding (*tahonero**) is paid by the number of cargas ground, and not by the week. A good tahonero gets ten dollars a week, or, if paid by the carga, from fifteen to twenty cents a carga. He has to be on hand night and day, sleeping close by his tahonas, and making his rounds several times in the night to see if all is well. It is hardly necessary to say that strict honesty is a most essential requisite in a tahonero, for his opportunities for stealing quicksilver, gold amalgam, and ore, are unlimited. In tahonas moved by spoons, the grinding, including salary and repairs, costs $1.40 a ton. In some haciendas the tahonas are placed in groups, and are driven by an overshot water-wheel, the power being transmitted by rude wooden gearing. Although these tahonas are smaller, they grind more rapidly, and the cost of attendance is less, so that the cost of grinding is probably not more than $1 a ton.

During the operation of grinding the free gold in the ores is caught by the quicksilver, and the greater part of the gold amalgam formed sinks to the bottom, and there accumulates in the cracks and cavities of the stones. When the slimes (*lama*) are fine enough they are watered freely, to facilitate the sinking of the rest of the gold amalgam; they are then dipped out into barrels, with the exception of about a barrelful, which is left behind to retain the gold amalgam, and are thrown into stone slime pits (*lameros*), where they are left to dry partially by evaporation and percolation before being put on the patio. When enough slimes have accumulated they are carried to the patio in barrels, and a *trilla*, called in some parts of Mexico a *torta*, is formed. The trilla varies in size according to the richness of the ore and the size and resources of the hacienda, but it seldom contains less than about 10 tons, of 2000 pounds each (sixty Mexican cargas), or more than 25 tons. In very small haciendas, trillas of from ½ ton to 2 tons are worked, but there the treading out is done by men and not by mules. Around the slimes, which are brought to the patio in a semi-liquid state, a dam of sand and boards is built up to confine them within limits; they are then left for several days, exposed to sun and wind, until the water evaporates and they acquire about the consistency of brickmaker's clay, which is the proper state for the beginning of work.

Leaving the slimes on the patio for the present, let us return to

* Pronounced *townero*.

those remaining in the tahona and containing the gold amalgam. After a variable number of charges have been ground, and from four to eight pounds of quicksilver have been taken up, a few ounces at a time in each tahona, the process of grinding is stopped, and the whole interior of the tahona is scraped out with most scrupulous care. The whole amount of material thus collected is washed in a pit, known as a *chuza*, and the gold amalgam is carefully collected. The chuza is about 3 m. in diameter, and 0.5 m. deep. It contains at one side a conical wooden bowl, 0.35 m. in diameter and 0.3 m. deep, whose edges rise about 0.05 m. above the cemented bottom of the large pit. A wooden trough conducts water to the pit, and opens into it directly over the bowl. The material to be washed is put into the trough, in which it is carried gradually along until it falls into the bowl. A man or boy sits over the bowl and keeps the material in agitation by stirring it continually with his foot. In this way the slimes to be washed are thoroughly disintegrated, the quicksilver and the amalgam fall to the bottom of the bowl, the heavier tailings collect in the pit, and the lighter ones are carried away by the water to a settling-tank, or run to waste. The tailings saved in the pit are concentrated by hand, and usually yield some very rich sulphurets, containing large quantities of both silver and gold (*cabezuela*). The gold amalgam is wrapped in a cloth, placed inside of a quicksilver flask with the bottom out, or in a small earthen pot, if too small for the flask, and retorted in the usual Mexican manner, of which a description is attempted further on. The resulting spongy mass of bullion is called *oroche*. The quicksilver used in collecting gold in the tahona is kept apart from that used for silver on the patio, as it is very rich in the precious metals, and will catch the free gold more quickly than fresh quicksilver.

The slimes left on the patio to allow the surplus of water to evaporate should be found to have, after an exposure of two or three days, according to the weather and the season of the year, about the consistency of brickclay. The first thing done with them is to turn them over with a spade, and trim up the mass until it assumes the appearance of a gigantic "dirt-pie," 7 to 15 m. in diameter and from 0.2 to 0.3 m. in thickness.

Twenty-four hours after the first spading, the trilla is salted (*insalmoro*). The quantity of salt used varies according to the character of the ore; but, for sulphuret ores that average $60 a ton, the quantity used should be from 35 to 40 liters a ton. Mules are then turned in and made to tread the mass for some hours, until, with the

help of several spadings, done while the mules are resting, the salt is thoroughly distributed through every part. The number of mules need not be so great as when the full charge of quicksilver and chemicals is in. The trilla stands in this condition over night; the mules then tread it for an hour or two to loosen it up; it is spaded over again, and the charge of quicksilver and sulphate of copper is added. This stage of the process is called *incorporo*. The amount of quicksilver added at the incorporo varies according to the nature of the ores and the special practice of the amalgamator (*azoguero*). The total amount required can be closely calculated from a fire-assay of the trilla. The yield of silver on the patio is usually calculated at 75 per cent. of the total amount contained in the ore, and the rule is to allow six pounds of quicksilver for each pound of silver, an additional 150 to 200 pounds just before washing to keep the silver amalgam in a fluid state and to promote its separation from the tailings, and 7 per cent. more for mechanical loss during the process. That is, if a represents the number of pounds of silver; b the number of pounds of quicksilver to be added to keep the rest in solution (*baño*); and x the number of pounds of quicksilver needed in all, then

$$x = 6a + b + \frac{7(6a + b)}{100}.$$

Of the quantity given by the above formula, from 150 to 200 pounds, as has just been remarked, are put in immediately before washing the trilla. Of the remainder, some amalgamators put in only two-thirds at the time of the incorporo, while others put in three-fourths or more. Those who believe in putting in a small charge at first say that by doing so they avoid mechanical loss, since the bulk of the quicksilver is not so long on the patio; others argue that this gain is visionary and does not equal the cost of putting in the quicksilver afterwards. Whatever the amount of quicksilver may be, it is emptied, ten or twelve pounds at a time, into a doubled piece of cotton cloth, and a sturdy laborer then walks all over the trilla, squeezing the cloth with both hands and flinging the quicksilver in a shower over the trilla, as it is forced in small globules through the pores of the cloth. Care must be taken not to fling any quicksilver away from the trilla on to the patio, and to distribute it uniformly; the rest of the operation is merely mechanical.

After the quicksilver has been added, the treading begins again with a full complement of mules, one for each ton and a half of ore in the trilla, and continues, with one spading over, for two hours.

Then the mules are again stopped and a hot solution of sulphate of copper is added. The amount to be added varies according to the nature of the ore. Ores with no sulphurets need very little sulphate; those with sulphurets and with traces of antimony, arsenic, or zinc, need the most; and only the experience of the amalgamator can tell him how much to add in each case. For sulphuret ores with only a trace of antimony and arsenic, and no zinc, it is customary to use about eight pounds for each ton of ore. In place of a part of the sulphate of copper some amalgamators use metallic copper in a finely divided state (*precipitado*), obtained by precipitation from sulphate of copper solution on iron or zinc. That obtained by aid of zinc is supposed to be distinctly better than that obtained by iron. When used together, five parts of sulphate and one part of the precipitated copper are added to the trilla. The use of metallic copper is thought to hasten the beneficiating and to lessen the loss of quicksilver. Magistral is not used in San Dimas.

After the sulphate is added the mules are driven around in the trilla until three o'clock in the afternoon, at which time the silver-bearing mud is carefully washed off their sides and hoofs, and they are led away to pasture. The day's work for the mules is from 6 A.M. to 3 P.M., and it is very fatiguing and exhausting to animals not brought up to it. They are driven around in teams of not more than nine, a driver standing in the middle of each team with the ends of the halters and a big whip. The mules are made to walk in spirals so as gradually to get over every part of the mass. In large trillas two teams are often at work at the same time.

The next day after the incorporo, another treading (*repaso*) of the trilla follows. Then there is a day's rest and exposure to the sun, whose effects are stimulated by one or more spadings. If the mass gets too stiff from evaporation, water is dashed over it to keep it sufficiently moist for easy working. The application of water should always be made in the early morning so as not to cool off the trilla and retard chemical action as it would do if added at midday or in the evening, when the trilla has been well warmed up by the sun's heat. The sun, indeed, is to the patio process what hot pans are to a regular silver mill. The influence of a warm, bright day upon a trilla is very great, while a cloudy or cold day retards its progress surprisingly. The progress of the amalgamation is carefully noted by means of assays (*tentaduras*), which are washed two or three times a day in the red earthen plate (*platillo*) before mentioned. This plate is about

0.18 m. in diameter, 0.007 m. thick, and about 0.02 m. at its deepest part.

An assay skilfully washed in such a plate presents several deposits of different substances. The plate is held in a slanting position at the end of the washing, and the different substances arrange themselves from above downward. First there comes a silvery white crescent of amalgam (*ceja*), then a black crescent of rich sulphurets, followed by a brownish deposit of pyrites with glittering specks, which runs off into sand at the lower edge. Below all a half spoonful of water contains a little ball of quicksilver. Most of the conclusions as to the state of the trilla are formed from the appearance of the upper rim of amalgam. When this is crystalline and hard to be worked by the fingers into a coherent mass, and no globules of quicksilver can be squeezed out of it, the amalgam is said to be "dry," or "strong" (*fuerte*), and the condition indicates the need of more quicksilver. When quicksilver is present in excess, a coherent mass is readily formed under the finger, and little globules of quicksilver are easily forced out. At the conclusion of the amalgamation the trilla is said to be *rendida;* and, when this is the case, the rim of amalgam is very fluid and at a touch resolves itself into small globules and vanishes away. When in this state, or approaching it, it is said to be weak (*debil*). A white, clear, bright appearance of the amalgam ring indicates that all is going well, while a dark, dirty color shows that something is wrong, and calls for a modification of the course of treatment. The ball of quicksilver in the lower part of the plate is also an indicator of the state of the trilla. When bright and clear, it shows that all is well; but if it is dark in color and, especially, if surrounded by a dirty, furry jacket, something is very much out of order. Sometimes the signs are all right, but the amalgamation does not advance; assays, washed on successive days, show the trilla to be at a standstill. This arises from a want of salt or from cold weather. Other abnormal appearances arise from too little sulphate, too little salt, too little or too much treading. Irregularities of this kind can only be effectively dealt with after considerable experience. As a general thing, however, a trilla, when it goes wrong, is treated either for "heat," arising from an overdose of sulphate and overworking, *i. e.*, from too energetic chemical action, or for "cold," arising from too little salt, too little sulphate, or too little treading. A heated trilla can often be restored, especially during the colder weather, by simply letting it stand a day or two, by dashing cold water over it, or by an application of lime and ashes.

The heating, however, generally involves a loss of quicksilver, as the sulphurets under such circumstances seem to attack it strongly. For a "cold" trilla the treatment is to supply what is wanting. This is ascertained by taking several larger assays, of from two to five pounds each, called *ijuelas*. To one of the assays a little salt is added, and to another, sulphate of copper. These are worked in a little by hand, and the masses are allowed to stand in a warm place. To a third assay no chemicals are added, but the mass is vigorously kneaded by hand for some time and is then left to itself. A tentadura of these assays, made after some hours, will generally show what the matter is with the trilla.

During the working of the trilla quicksilver is added from time to time, as determined by the indications of the assays, and, if everything goes well, the amalgamation ought to be finished after six or eight treadings. This desirable result depends, as has been already remarked, on the weather; gloomy, cold, and rainy days set a trilla back wonderfully, and a heavy rain will often make the mud so liquid that no work can be done on it for several days. Under favorable conditions the operation from incorporo to washing (*lava*) can be completed in sixteen days; while, under unfavorable circumstances, I have known a trilla to be on the patio between five and six weeks. About three weeks is the average time of working.

The best way is to pay the amalgamator by the carga of ore worked (twenty-five cents a carga or $1.66 a ton is the usual price), as by this system the work goes along much more rapidly than when the same man is paid a fixed salary. There is, however, a temptation to wash the trilla before the amalgamation is complete. To avoid this the proprietor should have some knowledge of the process, should give a general supervision to the operator, and pay constant attention to the assays.

As soon as the amalgamation is completed preparation must be made for washing the trilla within twenty-four hours. If the trilla is allowed to stand for a longer time, a further action takes place, called *desecho*, in which the surplus chemicals or the sulphur attack the amalgam and cause a great loss of silver. In order to guard against this danger, and to liquefy the amalgam, the 150 or 200 pounds of quicksilver before mentioned are added as baño, and preparations are made for washing and settling.

The ordinary settler (*lavadero*) (Plate II.), is an open box of stonework lined with cement, 2 m. long, 0.5 m. wide, and 1 m. deep, with a platform at its mouth on which to pile up the material to be washed,

a trough to fill it with water, and, at one end, a wooden gate pierced with a series of two-inch holes. These holes are kept closed by wooden plugs, and have a vertical trough outside to conduct the discharge to a quicksilver trap below.

At some haciendas of large capacity there are settlers, driven by water-power, that consist of large wooden tubs, some 2 to 5 m. in diameter, by about 3 m. in depth, in which revolve vertical shafts carrying four arms. These arms are pierced with square holes, in which are inserted vertically sticks of wood about 0.06 m. square, with intervals of 0.1 m. between them, the whole combination resembling a pale fence with the edges of the pales set diagonally to the side of the fence. These dashers reach to within about 0.3 m. of the bottom of the tub. A water-wheel by means of wooden gearing turns the upright shaft, and thus the contents of the tub are kept in violent agitation. About 0.8 m. from the bottom of the tub there is a hole about 0.15 m. in diameter through which to empty the tub, when desired; and about 0.15 m. above this there is a smaller hole, about 0.02 m. in diameter, for the taking out of assays.

In the ordinary box-settler the procedure is very simple. Inside the box, instead of wooden arms driven by a water-wheel, there are two men, whose business it is to keep the contents in motion. The box is partially filled with water, the men get into it with only a breech-clout to cover their nakedness, and the mud from the trilla is tumbled in, a spadeful at a time. By a dancing motion of the feet, the hands never being used, the mud is disintegrated and kept in suspension, so that the amalgam sinks to the bottom. More water and more mud are added, little by little, until the settler is filled to the highest hole in the wooden gate. The lighter tailings flow out through this hole with the water and are conducted by a series of gutters, well provided with catch-basins for quicksilver, to the settling tanks below. The muddy contents of the lavadero are partially discharged from time to time during the day through one of the lower holes in the wooden gate, but the amalgam goes on accumulating until the end of the operation. Care is necessary not to wash too fast, for fear of letting too much quicksilver run out of the settler, but the mass must be kept in constant agitation and not allowed to get too thick, for, if it gets too thick, the lower part of the settler becomes clogged with tailings from which the quicksilver can be separated only with difficulty.

In the tub-settler the machinery at first is made to revolve very fast, with the tub a third full of water, and the charge is then tum-

bled in and disintegrated at once. The tub is then filled nearly to the brim with water, and the dasher is reduced in speed and kept moving only just fast enough to keep the sand from settling, until several assays, taken from the small hole in the side, show that the quicksilver has settled. When this stage of the process is reached, the plug closing the large aperture is knocked out, and the tailings escape into the troughs leading to the settling tanks. The time of washing a charge of 300 pounds is about one hour. There are great advantages gained in using the water-power settlers. The operation can be kept up day and night, until finished, whereas with the box-settlers a clean-up must be made at nightfall; there is less chance for the workmen to steal, since only two men are needed besides the overseer, while the box-settler requires at least six men; there is less danger of the sand's settling and clogging the amalgam, or of the quicksilver's being carried off with the tailings; and as a whole the operation is under better control in every way. The first cost of the plant, however, is considerable, and, as surplus capital is not abundant in Mexico, the tub-settler is not used except in haciendas of the first class, and I am not sure that it is not of comparatively modern introduction even in these.

Whichever method of settling is adopted the last part of the operation consists in scraping the stones of the patio where the trilla lay, and the cracks between them, and throwing the scrapings into the settler with the last of the trilla.

The construction of the patio is simple. The common patio of the country is composed of irregular stones with surprisingly wide cracks between them. The flattest stones at hand are selected and laid in, without facing, to be smoothed down by natural wear. The cracks are filled with clay. The loss of quicksilver is not so great as one might suppose; with skilful working on an old patio the loss should not be over seven per cent., a part of which would be due to evaporation, and a part would be splashed away by the mules or lost in the crevices of the lavadero. The earth underlying the patio becomes in course of years well soaked with quicksilver, so that it sometimes pays to clean it up, especially if the hacienda is to be abandoned. Efforts have been made to improve on this older style, and in one hacienda in San Dimas the patio is made of brownstone, faced and fitted with great exactness. The cost was enormous, and it is doubtful whether a year's saving in quicksilver would pay more than a moderate rate of interest on the investment. In some places patios have been paved with pine planks, tongued and grooved. In

them the mechanical losses are small. They last for several years, being always kept flooded with water when not in use, and being protected besides by the strong preservative action of the sulphate of copper. I have also heard of patios built of asphalt and of artificial stone, both of which seem to be exceedingly well adapted to the purpose. Various mechanical expedients have been tried in San Dimas for the purpose of treading the trilla without mules. Rollers, wheels, and other devices have been used, but have all been abandoned. The day has gone by for investing money in an expensive plant for a process so radically defective, and the modern tendency is so manifestly opposed to such expenditure, that the most conservative Mexicans have already perceived it.

The yield of the washed trilla is chiefly found in a pool of liquid amalgam at the bottom of the settler. This amalgam is carefully dipped out, cleaned, dried, and weighed. The catch-basins in the gutter, through which the tailings had to pass on their way to the settling tanks, are also cleaned up, and the quicksilver they contained is weighed with the rest. The whole is then turned into a conical canvas bag (*manga*) to drain. The drippings are received in a hide trough (*pila*), and decanted into flasks, being practically, though far from chemically, free from silver. The dry amalgam (*copella*), left in the bag, is allowed to hang over night, and is then packed for retorting.

The retorts of the country are iron quicksilver flasks, with the bottoms knocked out, and the plugs firmly screwed in. These are first lined with brown paper, and then the amalgam is put in and rammed down firmly with aid of a wooden rammer and a heavy mallet. When all the amalgam is ready, the flasks are placed upon the furnace (*quemadero*). (See Plate II.) This furnace has a flat top, about 0.6 m. from the ground, pierced with four, six, or eight holes, 0.12 to 0.13 m. in diameter, which is slightly more than the outside diameter of a quicksilver flask. From these holes pipes of the same diameter lead well beneath the surface of water contained in a wooden basin below. The upper ends of the pipes are covered with iron plates pierced with many holes about 0.005 m. in diameter. Upon these plates the flasks filled with amalgam are placed, the open end downwards. A clay lute is then applied around the mouth of each flask, and the whole flask is covered with a neat coating of clay, about 0.005 m. thick. When all the flasks are in place and luted, a temporary wall of bricks is built around them, as they stand on the table of the quemadero, and a charcoal fire is kindled. The flasks are heated slowly until

the lute and the clay coatings have dried without a crack; then more and more charcoal is added until the whole mass of flasks is covered with glowing coals. The volatilized quicksilver finds its way down the iron pipes into the water, and condenses in a shining pool at the bottom of the basin. The water in the basin is constantly changing, and the condensation goes on until the operation is completed. Simple as the retorting is, it needs care. Too much heat will melt the silver, and cause it to follow the quicksilver down into the water; or, it may cause a too rapid formation of quicksilver vapor and an explosion, in which a flask of amalgam, hurled high in air, distributes its valuable contents far and wide. If the heat is too low, too much quicksilver is left behind with the silver. When the operation is properly conducted, the silver comes out in spongy bars (*plata pasta*), containing still about 1 per cent. of quicksilver, which can only be removed by melting the mass to an ingot. As a precaution against the possible presence of an excess of quicksilver, the purchaser of this kind of silver always has the privilege of heating the bars to a red heat before weighing them for final acceptance. If, however, they melt while undergoing the trial, the purchaser must pay for them at their weight before being put into the fire.

The quicksilver collected in the basin of the quemadero is not entirely free from silver. Before being put back into flasks, it must be strained through a closely woven cloth. This saves a certain amount of amalgam, called *estrujon*, which is much more pasty than that put in to be retorted. When a sufficient quantity of this kind of amalgam has accumulated, it is retorted over again. In the retorting there is a mechanical loss, from leakage, of a few pounds of quicksilver.

The silver obtained by the patio process is almost entirely free from the baser metals and from impurities of any kind. An assay of several bars gave an average of $\frac{994}{1000}$ of silver and $\frac{3\frac{1}{3}}{1000}$ of gold, leaving only $\frac{2\frac{2}{3}}{1000}$ for the baser metals, dirt, and loss. From 70 to 75 per cent. of the assay value of the ore in silver can be extracted by careful working, though the ordinary amalgamators do not get over 72 per cent. Some amalgamators claim that they can save 80 per cent. of the assay value, but this is extremely doubtful. Of the gold in the ore at least 40 per cent. is lost, about 20 per cent. of the remainder goes with the silver, and the rest is recovered from tailings, or is caught in the tahona.

The loss of quicksilver in the patio process is very great. There is always a fixed loss of an amount equal in weight to that of the silver

taken out; this is called *consumido*. Besides this, there is a mechanical loss on the patio and in washing of at least 7 per cent., which the least carelessness may increase to 10 per cent., and there is a further loss of from four to eight pounds in the retorting. So that, in the working of sulphuret ores that yield on the patio from $60 to $90 a ton, the total loss of quicksilver is, even under the best management, seven and a half pounds a ton; for ores of higher value, the loss is more.

The tailings from the washer run into two settling tanks, called *tanque* and *contratanque*, passing from the first into the second. A settling tank for trillas of twelve tons each is 5 m. long, 3 m. wide, and 1 m. deep. In these tanks the tailings leave the heavier sulphurets and a small quantity of amalgam with the heavier part of the sand. The lighter portions of the tailings flow through the contratanque to waste. There is a great difference in the contents of the two tanks. The tanque contains more and richer sulphurets, while the deposits in the contratanque are notably poorer in quality and less in quantity. In the subsequent concentrations it is customary to keep the material from the two tanks separate until a fire-assay determines their fitness to be mixed.

The concentration of the tailings is preceded by washing them a second time in the chuza, already described, for the purpose of getting out any remaining amalgam. The yield is usually three pounds or upwards, according to the size of the trilla and the carefulness of the former washing. For concentration the tailings from the chuza are piled up at one end of a masonry platform (*planilla*), from 1.5 to 2 m. square, with a slope of one in ten towards the workman. (Plate II.) The head of the platform is a sloping wall, which leaves space to accommodate a reserve of tailings, and at the foot there is a wide gutter with plenty of slowly running water. The operator (*planillero*) sits on a board thrown across the gutter at the lower left-hand corner of the planilla, and, lifting up the water with a horn spoon, about a quarter of a liter at a time, discharges it against the foot of a heap of tailings piled up at the head of the planilla. He commences at the lower left-hand corner, continues across the planilla, and then returns a little lower down, throwing each spoonful of water in such a way that it spreads out without splashing, and overlaps a little the area covered by the preceding one. When he has gone over the whole surface of the planilla in this way some four or five times, the sand has been partially washed away from the heavy sulphurets, which have settled near the upper part of the planilla, while the sand has worked along down to its lower end. The operator then removes the sand from the planilla

for about one meter upward from the gutter and throws it away. The remainder of the layer on the floor of the planilla he mixes up with the tailings at the head, and begins to throw on water as before. When the supply of tailings at the head is exhausted, more are added and the process continues until all the tailings have been washed, and there is left on the planilla a black heap of sulphurets (*polvillo*).

In order to concentrate the sulphurets a little more and to extract the last traces of amalgam it is customary to put them through still another process, called *bolichar*. This is performed in a wooden bowl, called *boliche*, (Plate II.), whose cavity is shaped like an inverted cone, somewhat truncated, 0.62 m. in diameter and 0.4 m. deep. Some boliches are 0.8 m. in diameter and proportionately deep, but, as they are made of a single piece of wood, such large ones are rare in San Dimas, which is "a long way from tall timber." Portions of the sulphurets are placed in such a bowl with plenty of water and are vigorously stirred for some minutes, after which they are allowed to settle. During the settling the outside of the bowl is tapped briskly with a mallet or a heavy stick of wood. This tapping is continued until the sulphurets settle down firmly and solidly in the bottom of the bowl, with all the water on top. The water is then absorbed by woollen rags and removed. On the top of the sulphurets there is a layer of pure sand. Below the sand there come first a layer of poor, brownish sulphurets called *colas*, and then the rich black sulphurets (*polvillo*). In the bottom of the bowl there is a small amount of liquid amalgam.

The colas, when a heap of them has accumulated, are roasted preparatory to working on the patio. The roasting furnace is made by spreading on the ground a layer of wood and kindlings, over which is spread a layer of colas about an inch thick; over the layer of colas there is another layer of wood, followed by another of colas, and so on alternately, always leaving a central opening, until a conical mound has been formed. The colas are put on wet, so as to be more easily handled. The mound, when completed, is covered with earth, set on fire, and allowed to burn out. In this method of roasting, one portion is over-roasted and sintered; a little is roasted just right; and the rest is under-roasted. The whole mass is mixed with sand, ashes, and half-burned sticks. The sticks are taken out by hand and the mass of colas is thrown into a tahona to be reground. It is afterwards mixed with ordinary ore and worked on the patio.

The concentrated sulphurets are sent to the port of Mazatlan, and thence shipped to Germany, for the account of the mine, to be worked in the government establishments there. Notwithstanding higher

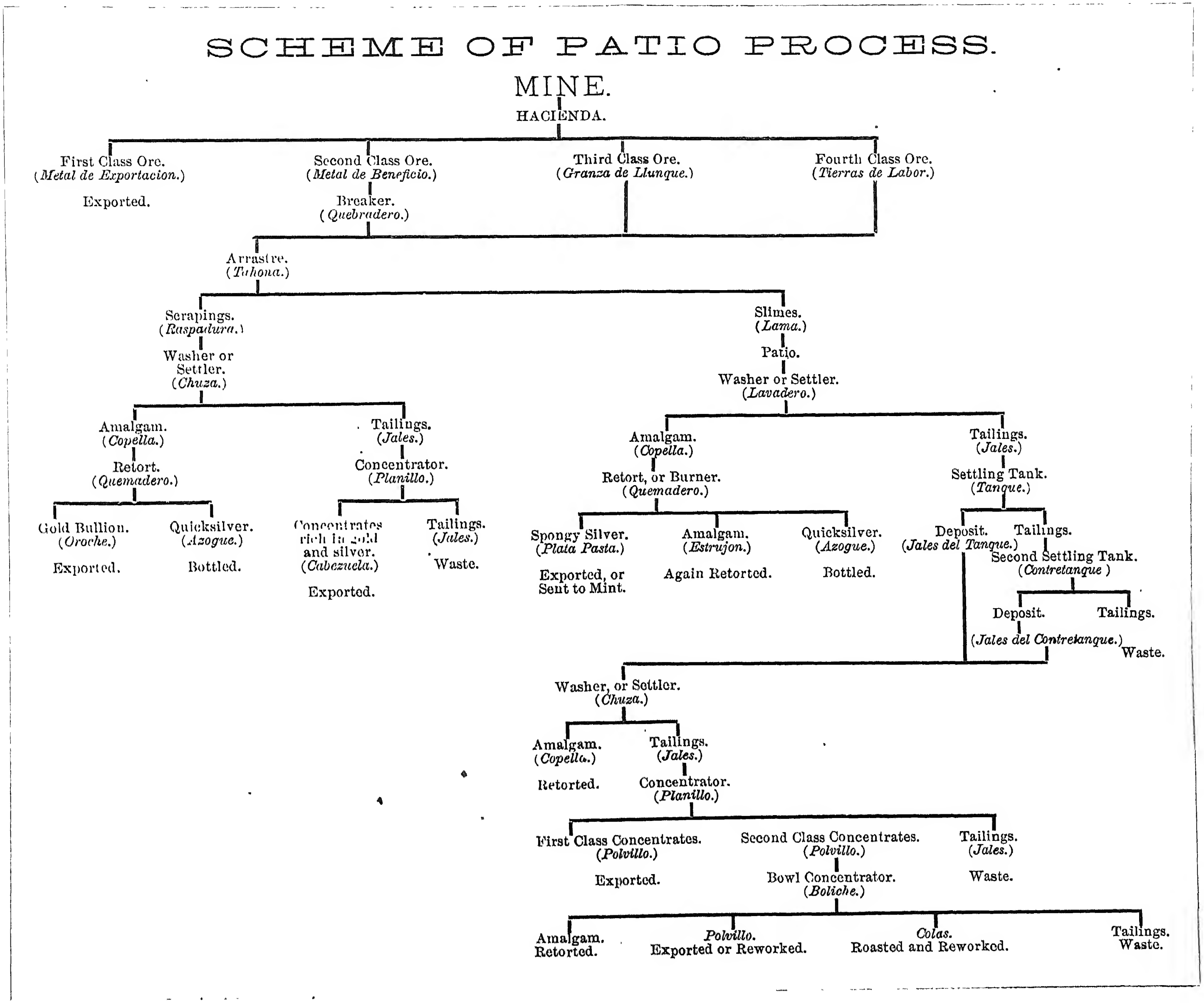
freights, etc., the returns are from 15 to 20 per cent. better than would be obtained by sending the same sulphurets to San Francisco. The forwarding houses in Mazatlan usually make an advance of 70 to 75 per cent. on the assay value of the sulphurets, for which no interest is charged unless the returns are delayed beyond a certain number of months. The first-class ores mentioned above are sent in the same way.

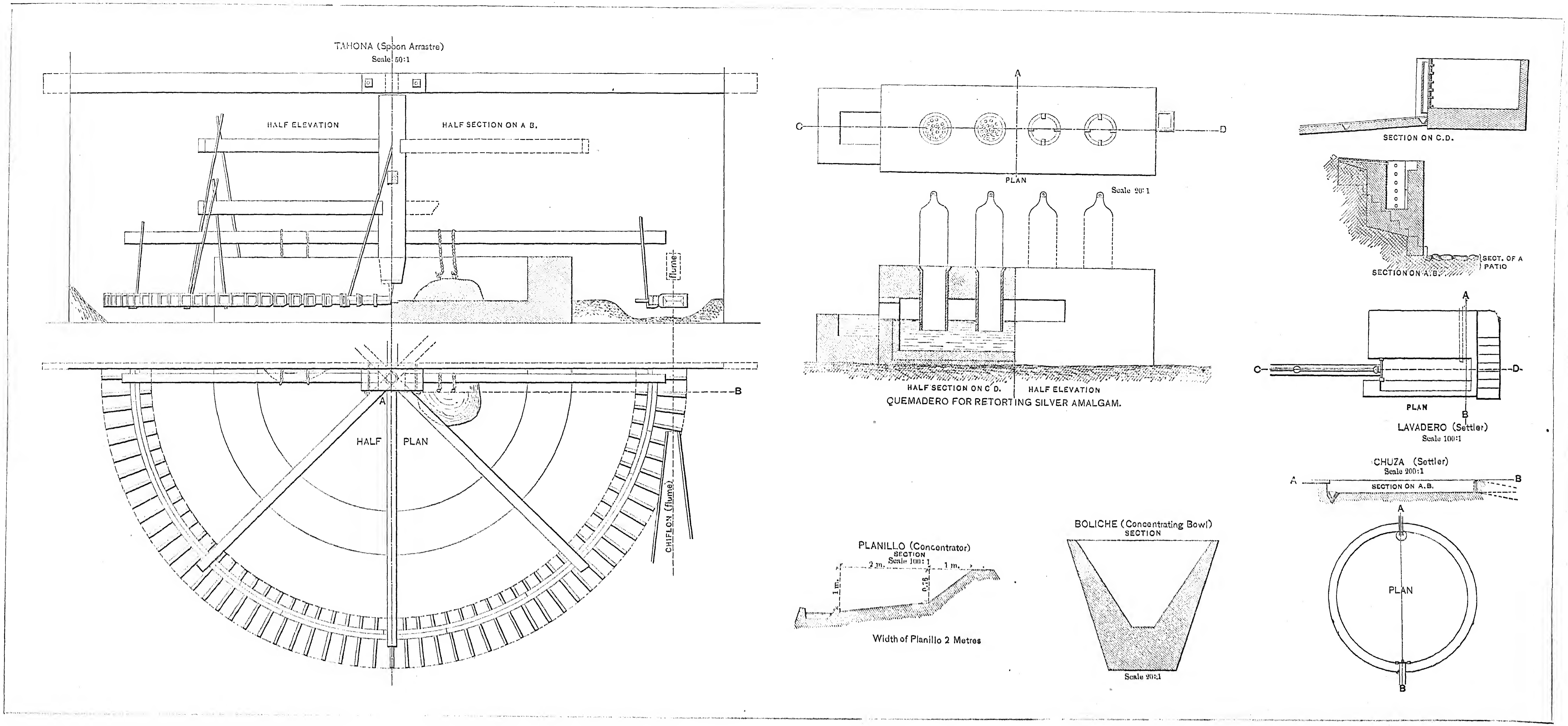
The cost of working ore upon the patio is very great. The following figures are from a hacienda where ores were worked whose average yield was sixty dollars a ton.

Process.	Cost per ton of 2000 lbs.	Remarks.
Breaking,	$ 1 53	Breaking a ton of large ore (*gabarro*) costs $2.66; but, as smalls (*granza*), which need no breaking, are also worked, the average cost is as stated.
Grinding,	1 40	
Scraping tahonas,	13	Cleaning up to get out gold amalgam.
Carriage of slimes from tahona to patio,	60	
Mules,	1 73	Cost of hired mules.
Labor,	1 80	Including driving and caring for mules, spading trilla, and washing.
Salt,	2 80	At $6.00, Mexican, per carga of 98.3 liters.
Sulphate of copper,	1 33	At $0.25, Mexican, per pound.
Charcoal, for retorting and assaying,	33	At $0.37½, Mexican, per *arroba*.
Quicksilver,	4 68	At $0.62½, Mexican, per pound.
Salaries, general expenses, etc.,	6 66	Including keeping and feeding of mules.
Repairs,	2 33	
Concentration of sulphurets,	2 26	
Total,	$27 58	

The above does not include cost of superintendence nor interest on cost of plant. The trillas upon which this calculation was based were small, averaging only ten tons. The expense of trillas of from fifteen to twenty-five tons would be proportionately less in the items of scraping tahonas, mules, labor, repairs, and general expenses, and there would also be a smaller mechanical loss of quicksilver.

In a large hacienda, where the tahonas were in two groups and were worked by gearing from an overshot water-wheel; where the breaking was done by wooden stamps shod with iron, and also driven


SCHEME OF PATIO PROCESS.
MINE.
HACIENDA.
First Class Ore. (Metal de Exportacion.)
Exported.
Second Class Ore. (Metal de Beneficio.)
Breaker. (Quebradero.)
Third Class Ore. (Granza de Llunque.)
Fourth Class Ore. (Tierras de Labor.)
Arrastre. (Tahona.)
Scrapings. (Raspadura.)
Washer or Settler. (Chuza.)
Amalgam. (Copella.)
Retort. (Quemadero.)
Gold Bullion. (Oroche.)
Exported.
Quicksilver. (Azogue.)
Bottled.
Tailings. (Jales.)
Concentrator. (Planillo.)
Concentrates rich in gold and silver. (Cabezuela.)
Exported.
Tailings. (Jales.)
Waste.
Slimes. (Lama.)
Patio.
Washer or Settler. (Lavadero.)
Amalgam. (Copella.)
Retort, or Burner. (Quemadero.)
Spongy Silver. (Plata Pasta.)
Exported, or Sent to Mint.
Amalgam. (Estrujon.)
Again Retorted.
Quicksilver. (Azogue.)
Bottled.
Tailings. (Jales.)
Settling Tank. (Tanque.)
Deposit. (Jales del Tanque.)
Tailings.
Second Settling Tank. (Contretanque)
Deposit. (Jales del Contretanque.)
Tailings.
Waste.
Washer, or Settler. (Chuza.)
Amalgam. (Copella.)
Retorted.
Tailings. (Jales.)
Concentrator. (Planillo.)
First Class Concentrates. (Polvillo.)
Exported.
Second Class Concentrates. (Polvillo.)
Bowl Concentrator. (Boliche.)
Tailings. (Jales.)
Waste.
Amalgam. Retorted.
Polvillo. Exported or Reworked.
Colas. Roasted and Reworked.
Tailings. Waste.



TAHONA (Spoon Arrastre)
Scale 50:1
HALF ELEVATION
HALF SECTION ON A B.
flume
HALF
PLAN
A
B
CHIFLON (flume)
C
D
A
PLAN
Scale 20:1
HALF SECTION ON C D.
HALF ELEVATION
QUEMADERO FOR RETORTING SILVER AMALGAM.
PLANILLO (Concentrator)
SECTION
Scale 100:1
2 m.
1 m.
1 m.
0.76
Width of Planillo 2 Metres
BOLICHE (Concentrating Bowl)
SECTION
Scale 20:1
SECTION ON C.D.
SECTION ON A.B.
SECT. OF A PATIO
A
C
D
B
PLAN
LAVADERO (Settler)
Scale 100:1
CHUZA (Settler)
Scale 200:1
A
B
SECTION ON A.B.
A
PLAN
B

by a water-wheel; and where the washing was done in a water-power washer, the charges in detail, for working a trilla of nineteen tons, were as follows:

Process.		Cost per ton of 2000 pounds.
Breaking, grinding, and use of tools,		$6 66
Amalgamator's wages,		1 66
Scraping tahonas,		16
Carrying and washing scrapings,		11
Concentrating tailings of scrapings,		07
Carrying slimes from tahona to patio,		42
Mules, and keeping,		3 72
Labor, spading trilla, and mule driving,		1 60
Labor, washing trilla,		56
Charcoal, for retorting silver,		47
Concentrating tailings of trilla,		2 06
Materials:		
Salt, 600 pounds, at 8 cents,	$48 00	2 53
Sulphate of copper, 125 pounds, at 25 cents,	31 25	1 65
Precipitated copper, 25 pounds, at 66 cents,	16 50	87
Quicksilver, 133 pounds, at $62\frac{1}{2}$ cents,	83 12	4 37
Total,		$26 91

The total cost of $26.91 a ton for custom-work in this hacienda includes a charge for profit to the owners on all the items except the four items of "materials," which were originally higher priced; they have been reduced to the same prices as in the other table to facilitate comparison. To the owners of the hacienda the cost of beneficiating would certainly not exceed $25 a ton, making a difference of $2.58 a ton in favor of the hacienda driven by water-power in the way that I have described.

The only positive advantage of the patio process lies in the cheapness of the plant. Rough stones and hydraulic lime for tanks, washers, and tahonas are procurable almost anywhere. Timber for the woodwork is also generally plenty; no elaborate carpentry is needed; and with a rawhide or two for thongs the outfit is complete. In no other country than Mexico would such a process have taken root, and only the richness of the mines and the want of transportation have enabled it to survive even in that most conservative land.

Some of its disadvantages are the constant bother, to say nothing of the expense, in working with mules, and the frequent handling of the ore, quicksilver, and amalgam, which, besides being expensive, gives excellent chances for robbery. There is a great waste of materials, and of quicksilver, gold, and silver. Large quantities of tailings are produced, which must be concentrated and shipped, with

extra expense and with loss of interest on a considerable amount of capital. Last, and very far from least, is the great disadvantage of time; four weeks, at least, are needed under the most favorable circumstances, from the arrival of the ore at the hacienda until the extraction of the silver, and this time may be greatly lengthened, or even doubled, by variations of weather and of temperature. Even the Mexicans are beginning to be alive to these considerations, and it is probable that in a decade or two the patio haciendas now in operation will be memories of the past.

In the consideration of this process I have made no effort to investigate its reactions. Several learned chemists have, I believe, written on this branch of the subject, but I do not know that they have even approached an agreement. I may well be excused from entering into a discussion which has already proved itself so very unprofitable.

Accompanying this paper I give a scheme of the patio process (Plate I), from which the relations of the various products can be readily seen, and also drawings (Plate II) of the apparatus used.

NOTE.—The Mexican pound has sixteen ounces, and weighs, according to the tables of the Durango Mint, 0.46024634 kilogram. This is the weight referred to in the preceding paper wherever the word pound occurs; the ton is 2000 of these pounds. The "marc" used in Mexico as a unit in weighing silver and gold weighs eight ounces, or half a Mexican pound.

CHARCOAL AS A FUEL FOR METALLURGICAL PROCESSES.

BY JOHN BIRKINBINE, PHILADELPHIA.

THE iron industry of the United States, and, in fact, of the world, was established with charcoal as fuel. Long before the value of mineral coal was recognized, the carbonization of wood was carried on in connection with various metallurgical processes, but at the present time we look upon establishments using charcoal as the remnant of a former greatness, and are apt to sympathize with the operators because they have no other fuel to depend upon. In the iron

industry there are now a number of works consuming charcoal which are believed to exist only because some of our ancestors erected them in particular locations. With but few exceptions, however, these locations are found to be advantageous, both on account of a good wood supply and the existence of remarkable beds of iron ore. Constructed at a time when transportation facilities were limited, a number of such plants have no railroad connections, but some which have been remodelled and operated in the light of present knowledge are very successful ventures.

It is proper, in view of the prevalent opinion concerning the early abandonment of charcoal as a metallurgical fuel, that before the processes of manufacture are considered some idea as to the quantity consumed be obtained, for, while in many locations the denudation of forests fixes a limit to the manufacture of charcoal, and in other instances a wilful waste destroys what might be a permanent supply of wood, the amount and value of charcoal used is not generally appreciated.

Charcoal at present produces 18 per cent. of all the pig iron made in the country. In the year 1881, 638,838 net tons of pig iron and 84,606 net tons of blooms and billets,* a total of 723,444 net tons, were made with this fuel, consuming about 1,000,000 net tons of it. Never in the history of the iron trade have so great quantities both of pig iron and blooms been made with charcoal as fuel, and it is probable that the product of 1882 will considerably exceed that of 1881. The world's yearly production of charcoal pig iron is nearly 2,000,000 gross tons.

If to the amount of this fuel used at iron-works, we could add that consumed in the various smelting-works of the silver and other metallurgical industries, the total annual consumption of charcoal in the United States would be found to approximate 2,000,000 net tons. This, therefore, establishes the importance of considering this fuel, so far as quantity is concerned, and the quality may now be investigated.

Analysts tell us that average wood is composed of 40 per cent. of carbon, 20 per cent. of water, and 20 per cent. of hydrogen and oxygen, in proportions closely approximating those in which they form water. These even percentages are affected by small quantities of ash, and by special compounds differing in various woods.

The following analyses of wood and charcoal will be of interest.

* This does not include blooms made in charcoal forge fires in rolling mills.

Analyses of Dried Woods. By M. Eugene Chevandier.

Woods.	Composition.				
	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Ash.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Beech, ...	49.36	6.01	42.69	0.91	1.00
Oak, ...	49.64	5.92	41.16	1.29	1.97
Birch, ...	50.20	6.20	41.62	1.15	0.81
Poplar, ...	49.37	6.21	41.60	0.96	1.86
Willow, ...	49.96	5.96	39.56	0.96	3.37
Average, ...	49.70	6.06	41.33	1.05	1.80

The following table, prepared by M. Violette, shows the proportion of water expelled from wood at gradually increasing temperatures:

Temperature.	Water Expelled from One Hundred Parts of Wood.			
	Oak.	Ash.	Elm.	Walnut.
257° Fahr., ...	15.26	14.78	15.32	15.55
302° Fahr., ...	17.93	16.19	17.02	17.43
347° Fahr., ...	32.13	21.22	36.94 ?	21.00
392° Fahr., ...	35.80	27.51	33.38	41.77 ?
437° Fahr., ...	44.31	33.38	40.56	36.56

The wood operated upon had been kept in store two years.

When wood, which has been strongly dried by means of artifical heat, is left exposed to the atmosphere, it reabsorbs about as much water as it contains in its air-dried state.*

* *Vide* Combustion of Coal, Barr, p. 36.

A Table Showing the Composition of Charcoal Produced at Various Temperatures. By M. Violette.

Temperature of Carbonization.		Composition of the Solid Product.				Carbon for a given weight of Wood.
		Carbon.	Hydrogen.	Oxygen, Nitrogen, and Loss.	Ash.	
Centigrade.	Fahrenheit.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
I, . . 150°	302°*	47.51	6.12	46.29	0.08	47.51
II, . . 200°	392°*	51.82	3.99	43.98	0.23	39.88
III, . . 250°	482°	65.59	4.81	28.97	0.63	32.98
IV, . . 300°	572°	73.24	4.25	21.96	0.57	24.61
V, . . 350°	662°	76.64	4.14	18.44	0.61	22.42
VI, . . 432°	810°	81.64	4.96	15.24	1.61	15.40
VII, . . 1023°	1873°	81.97	2.30	14.15	1.60	15.30
VIII, . . 1100°	2012°	83.29	1.70	13.79	1.22	15.32
IX, . . 1250°	2282°	88.14	1.42	9.26	1.20	15.80
X, . . 1300°	2372°	90.81	1.58	6.49	1.15	15.85
XI, . . 1500°	2732°	94.57	0.74	3.84	0.66	16.36
Melting-point of platinum, .		96.52	0.62	0.94	1.95	14.47

The wood experimented on was that of black alder or alder buckthorn, which furnishes a charcoal suitable for gunpowder. It was previously dried at 150° C. = 302° F.

In carbonization, the water, oxygen, and hydrogen are driven off with some loss of carbon, the greater part of the carbon and the ash remaining; we therefore have a fuel which when anhydrous is practically pure carbon, the percentage of ash seldom reaching 2 per cent., but the open porous structure permits the absorption of considerable atmospheric moisture, and much of the charcoal as used in actual smelting or refining may be considered as containing

Carbon, say	90 per cent.
Ash, say	1 "
Water, say	9 "

The improved methods of manufacture, however, largely reduce the chances for absorbing moisture. In metallurgical processes the

* The products obtained at these temperatures cannot properly be termed charcoal.

water in the charcoal is driven off in the first stages, and therefore it does not ordinarily affect the value of the fuel except where it is bought or charged by weight. No attempt will be made to discuss the relative merits of different fuels, as exhibited in their chemical composition, but some facts will be presented as to work done to demonstrate the character of the fuel under consideration.

In the very complete census report on the iron and steel industries for 1880, prepared by Mr. James M. Swank, the following statistics are given:

Pig iron produced in 1880.	Net tons.	Net tons.
With anthracite coal,	1,112,755	
" bituminous coal,	1,515,107	
" mixed anthracite and coke,	713,912	
		3,341,774
" charcoal (cold blast),	79,613	
" " (hot blast),	355,405	
		435,018
Furnace castings,		4,229
Total,		3,781,021

Allowing a proportionate amount of castings to each kind of fuel, we can safely estimate the quantity of iron produced in blast-furnaces with mineral fuel at 3,345,450 net tons, and with charcoal at 435,571 net tons. The fuel consumption, in producing this metal, is stated as

2,615,182	net tons anthracite coal,
1,051,753	" " bituminous coal,
2,128,255	" " coke,
5,795,190	" " total mineral fuel,
53,909,828,	bushels charcoal.

Estimating the charcoal at twenty pounds a bushel (a fair average), its weight would be 539,098 net tons.

This, therefore, gives as the average consumption per net ton of pig iron: 1.732 net tons of mineral fuel, 1.238 net tons of charcoal. When it is remembered that most of the charcoal blast-furnaces are of small size, that many of them are poorly equipped, and that one-fifth of the iron produced with this fuel was made with cold-blast, thus augmenting the quantity of fuel consumed, the value of charcoal as a fuel for producing iron is manifest.

In the same report the records of six consecutive weeks' work of eleven mineral coal and coke furnaces, and eleven charcoal furnaces show the following averages:

	FURNACES USING	
	Mineral fuel.	Charcoal.
Diameter of bosh, feet, . .	17	10.5
Height, feet, ...	70	47
Temperature of blast, degrees F.	1035	770
Fuel per gross ton (pounds), .	2569	2203
Gross tons made per week, .	557	218
Burden per pound of fuel, .	2.23	2.506

The above were selected for their exceptionally good records.

While its value as a fuel, practically free from deleterious substances, is important, the physical structure of charcoal is probably of greater advantage. This will be evident when the fact above mentioned is considered, viz., that charcoal as ordinarily charged does not contain over 90 per cent. of carbon. Comparisons of the operation of blast-furnaces show that not only is the fuel consumption per ton of pig iron less with charcoal than with mineral fuels, but that the output is greater per cubic foot of capacity, although the bulkiness of charcoal prevents as much ore being in the furnace at a given time as is possible with mineral fuel.

Having considered the quantity of this fuel now used and its quality, the methods of manufacture may receive attention. Formerly all charcoal was made in heaps or meilers. In American practice kilns are rapidly superseding the more wasteful method, and retorts are now taking the place of kilns and meilers in many cases.

Meiler charring should not be employed except under peculiar conditions, and it has been fully described in the *Handbook for Charcoal Burners*, by Svedelius.

Professor Egleston presented to the Institute, at the Pittsburgh meeting, in May, 1879,* a very complete paper on "The Manufacture of Charcoal in Kilns." It is, therefore, only necessary at present to consider the system of carbonization in retorts and compare it with the other processes.

At the Lake George meeting of the Institute, in October, 1878,† I presented a paper "On the Production of Charcoal for Iron Works," in which the subject of carbonizing the wood in closed vessels was considered and reasons were advanced for the more general adoption of this method. During the discussion which followed it was claimed that the collection of acetates was not practicable when charcoal was manufactured for commercial purposes. It is now my privilege to

* *Transactions*, viii., 373. † Ib., vii., 149.

state that the production of charcoal is successfully carried on both in kilns and retorts, and the acetic vapors arising from the carbonization are condensed and made into commercial products.

There are now in operation at the Bangor Furnace, Michigan, fourteen kilns of eighty cords capacity, in which 16,000 cords of wood are annually carbonized, and the Elk Rapids Furnace, Michigan, also has 22 one-hundred cord kilns in which 40,000 cords of wood are each year converted into charcoal; the acetic vapors being exhausted from all of these kilns by Peirce's patent method and converted into acetate of lime and methylic alcohol. The two plants produce daily 17,000 pounds of acetate of lime and 250 gallons of alcohol. In addition, the Elk Rapids furnace has 3 one-hundred cord kilns, and 10 sixty cord kilns which are not constantly in use.

That the charcoal is not deteriorated by the collection of the acetic vapors is proven by the reports of the managers of these plants and by the remarkable records made by both these furnaces. It is doubtful if any other charcoal blast-furnace in the country can show as good work for four consecutive years as that at Bangor. Concerning the discussion above referred to, Major Pickands, the manager, says: "We do not extract acetic vapors; nature throws them off from the wood in process of carbonization, whether that process takes place in a kiln, retort, or dirt pit, and we capture the vapors and utilize them."

The financial success of the chemical department at Bangor encouraged the more pretentious venture at Elk Rapids, and late reports from the latter furnace place it in the front rank for economical fuel consumption and large output.

A number of retorts are scattered throughout the country. The Baltimore Iron Company have sixteen horizontal retorts, the Port Leyden Iron Company have twenty-four Mathieu retorts, and a number of iron works now have or are erecting the latter. The Mathieu retort has met with most favor, and at present is being more rapidly adopted than others, because of its form and setting, and on account of the inventor's making the quality of his charcoal the first claim, and the quantity of acetates collected a secondary consideration. The forms of retorts in use in this country are generally iron cylinders, set either horizontally in nests over fire-places, or vertically with flues surrounded them. Departures from this plan are the retorts at Coloma, Michigan, where a semi-cylindrical iron bottom is covered by a fire-brick arch, these forming a complete cylinder, and the Messau still, in which the carbonization is carried on by the use of super-

heated steam. This last, however, is principally employed with resinous woods.

The Baltimore Iron Company report as the average yield of the horizontal retorts fifty-two bushels per cord. The Port Leyden Iron Company have been obtaining sixty-six bushels per cord. Part of this difference may be accounted for by the age and character of the wood used, but it is probable that a less uniform carbonization in the horizontal cylinders is obtained than in the Mathieu retorts.

These latter are made nearly crescent-shape to give a practically uniform thickness of wood, and are set inclined over fire-places. This method of setting is advantageous on account of the convenience of filling and discharging, and of its permitting any condensed acid to drain from the retorts when cold, thus preserving the life of the retorts. It is claimed that while in operation there is little danger of the iron in the retorts being attacked by acetic acid, because the heat maintained is sufficient for volatilization. Some two hundred of the Mathieu retorts are in place or in process of erection at various works located in different sections of the country. They are constructed of a bottom plate of one-half inch wrought iron, which is protected by an arch of fire-brick, the upper portion being formed of one-eighth inch wrought iron, connected to the bottom by angle irons. A suitable cast-iron head, with removable door, is placed on either end, to which a nozzle for conveying the vapors from the retort is secured. Each retort is about fourteen feet long. The capacity is one cord of wood ordinarily cut sixteen inches long. With air-dried wood, as commonly used, the retorts require about sixteen hours for carbonization.

There are so many commercial uses to which acetates and acetic acid can be applied, and such possibilities open to any process which cheapens them, that it is strange so little attention has been bestowed upon collecting the immense quantities now wasted in charcoal production, while large works for distilling these products from wood have been erected at, or near to, our cities for supplying print works, etc.

The following table shows the proportion of volatile gases which are produced in making charcoal at different temperatures, and indicates how much of the contents of the wood may be lost, even at the ordinary temperatures of carbonization :

Temperature Degrees at which Carbonization was Effected.		Products of the Decomposition of 100 parts by weight of Wood by Carbonization at Different Temperatures.				
		Composition of the Solid Matter or Charcoal.			Composition of the Matter Volatilized.	
Centigrade.	Fahrenheit.	Carbon.	Gaseous Elements, (H,O,N).	Ash.	Carbon.	Gaseous Elements, (H,O,N).
I, . . 150°	302°	47.51	52.41	0.08		
II, . . 200°	392°	39.95	36.97	0.18	7.56	15.34
III, . . 270°	518°	26.17	10.65	0.32	21.34	41.52
IV, . . 350°	662°	22.73	6.75	0.18	24.78	45.56
V, . . 432°	810°	15.40	3.25	0.22	32.11	49.02
VI, . . 1023°	1873°	15.37	3.12	0.26	32.14	49.11
VII, . . 1100°	2012°	15.32	2.86	0.22	32.19	49.41
VIII, . . 1250°	2282°	15.81	1.91	0.22	31.70	50.36
IX, . . 1300°	2372°	15.86	1.40	0.20	31.65	50.89
X, . . 1500°	2732°	16.37	0.83	0.11	31.14	51.55
XI, Beyond 1500°, melting-point of platinum.		14.48	0.23	0.29	33.03	51.97

But the importance of carbonizing in closed vessels is not based alone on the value of acetic vapors collected, and the market for them may be a matter of secondary consideration. It is the possibility of obtaining a greater yield from a given amount of wood which makes retorts valuable to those using charcoal as a fuel for metallurgical processes. Liberal averages for the various methods of producing charcoal from ordinary air-dried wood of medium age and size are, for meiler charring, 30 bushels per cord; for kiln charring, 45 bushels per cord; for retort charring, 60 bushels per cord. A cord of wood will, therefore, produce as much charcoal in retorts as one and one-third cords in kilns, or as two cords in meilers. The reason for this is, that, as the heat is applied extraneously, none of the wood in the retort is consumed, while in the kiln part of its contents are burned to carbonize the balance, and the meiler, being more open, less controllable, and of smaller content, wastes more wood than the kiln.

The saving of a large percentage of the wood required (particu-

larly in some of the Western States, where charcoal sells as high as thirty cents per bushel), would soon pay for a plant of retorts, even if all the acetic vapors were wasted.

The first cost of a battery of retorts is considerable, but, based on the outlay per bushel of charcoal made, it compares favorably with the expense of kilns. When placed in nests, fuel for heating the retorts is seldom required, for the uncondensable gases resulting from the carbonization are generally sufficient to maintain the temperature of the retorts at the point desired. The amount of these gases available is insufficient in some parts of the process, and in others abundant, but where a number of retorts are operated together the deficiency of one is made up by the others. The convenience of filling and emptying retorts as compared with kilns compensates for the cost of cutting the wood.

The census statistics of 1880 show that eighteen billion feet of boards were cut in that year. Of this amount there was probably a waste of one-half cord in tops and branches left to rot in the clearings, or in slabs burned at the mills, for each thousand feet of boards sawed, or 9,000,000 cords. This would have produced by improved methods probably 50,000,000 bushels of charcoal, or two and one-half times the quantity annually consumed in the country. There is, therefore, an opportunity to produce, from what is now wasted, fuel to do much to advance the industries of our country, and this paper has been prepared to indicate the possibilities of manufacturing charcoal economically in locations where, if it received consideration, most satisfactory results might follow.

If the expensive and wasteful process of producing charcoal in heaps or meilers is persisted in, the practical abandonment of this fuel may easily be prophesied. But if the economies of manufacture are carefully considered, charcoal will be found to be in many locations the cheapest fuel accessible for metallurgical purposes. A number of Pennsylvania charcoal furnaces produce pig-iron with no greater money expenditure for fuel per ton of metal, than their near neighbors who use mineral fuels, and in that State the more modern methods of producing charcoal are not generally adopted.

Generally where woods are felled to produce charcoal, it is considered as sacrificing timbered area. Such is not, or should not be the case; for it is compatible with successful operation to carry on the production of charcoal in connection with lumbering, or other kindred industries. There is less merchantable timber consumed to-day, in the manufacture of charcoal, than is left in the woods by

those who strip bark for tanneries, or cut railway sills and telegraph poles. The waste of the saw-mills has been referred to above and needs no further comment.

An industry dependent upon charcoal as fuel must, to be permanent, maintain large forest areas, thus benefiting the surrounding country; and much of the growing timber, being suitable for other purposes than charcoal-making, will be so used whenever the compensation is greater. Anomalous as it may at first appear, the probabilities are that, in the near future, the large consumers of charcoal will be among the most enthusiastic patrons of forest cultivation and preservation.

THE ESTIMATION OF MINERAL OIL IN THE PRESENCE OF OTHER OILS.

BY CHARLES C. HALL, WORCESTER, MASS.

THE following procedure in estimating mineral oil when mixed with vegetable or animal oils, is the result of a long series of experiments based on the method suggested by Sir William Thompson and Mr. A. H. Allen, in a paper read before the Royal Society.*

Four to five grams of the oil under examination are weighed out into a porcelain capsule of 75 c.c. capacity. Thirty c.c. of a 10 per cent. solution of potassium-hydrate in alcohol are added, and the capsule covered with a watch-glass is placed in a water-bath heated to about 93° C. The mixture of oil and alkali should be stirred frequently, and after three-quarters of an hour it is boiled with stirring. This will secure the complete saponification of all the vegetable or animal oil. After the boiling has been continued some time, and most of the alcohol is expelled and a thick scum of soap forms on the surface, a little bicarbonate of soda is added to convert the excess of caustic alkali into carbonate. When the contents of the capsule have become pasty an equal bulk of fine, clean sand is stirred in. This makes the soap granular, and facilitates the removal of the last traces of alcohol. The capsule is now heated for two hours more on the water-bath. After cooling, the contents of the capsule are transferred to a short-necked funnel, having a thin plug of asbestos, and washed with petroleum-ether, or some other light petroleum spirit. The ether dissolves out the mineral oil from the soap, and is best collected in a quarter-liter flask having a short neck. The ether can be applied conveniently and effectively by a small wash-bottle. Care must be taken to effect a complete removal of the oil

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* Nature, vol. xviii.

from the soap by means of the ether. This can be tested by letting a drop of the ether, as it comes through, fall on a piece of tissue-paper. If there is no greasy stain left after the ether evaporates, the solution may be considered complete.

Most of the ether is removed from the oil by distillation and can be saved. The heat of the water-bath is sufficient to boil the ether, and the fumes can be condensed by passing them into a condenser. The oil is now transferred to a weighed 50-c.c. flask which has a hole blown in its side, and dry, warm air is forced into the flask through its neck in order to remove the last traces of the ether. The flask should not be heated above the point where it can be borne in the hand; if this precaution is heeded, there is no danger that any of the oil will be volatilized. The passage of the air should be continued until the flask and oil are constant in weight.

Sperm oil cannot be separated from mineral oil by this method owing to the impossibility of completely saponifying it.

Experiments with sodium-hydrate instead of potassium-hydrate did not give good results.

The following quantitative determinations of mineral oil in mixtures made for the purpose show the accuracy of the method:

Kind of Fat Oil in the Mixture.	Percentage of Mineral Oil in the Mixture.	Percentage obtained by Analysis.
Olive Oil, ..	61.11	61.10
	66.79	66.75
	25.39	25.13
	21.20	21.14
Lard Oil, ...	32.69	32.01
	43.05	42.95
Linseed Oil, .	3.75	4.05
	10.63	10.68
	1.68	1.90
Neatsfoot Oil,	18.75	18 75

In a mixture of neatsfoot and mineral oil in unknown proportions, four analyses showed the per cent. of mineral oil to be as follows: 72.05, 72.00, 71.85, and 72.10.

In a sample of fish-oil, supposed to be pure, there were obtained the following percentages of mineral oil: 34.58, 34.90, 34.50, and 34.85.

Machine-oil, composition unknown, contained of mineral-oil 64.63, 64.67.

A cylinder-oil contained of mineral-oil 71.00, 71.60.

A lubricating oil claimed to be pure animal oil was found to be adulterated with 77.25 per cent. of mineral oil.

NOTES ON SOME REACTIONS OF TITANIUM.

BY MRS. ELLEN H. RICHARDS, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, BOSTON.

It is of importance to analysts to have a ready means of detecting the presence of small quantities of titanium in iron ores and in certain fluxes and slags. The method given in Elderhorst's *Blowpipe Analysis* (fusion with potassium hydrogen sulphate) requires considerable practice, in order so to regulate the heat that the titanium oxide shall become soluble.

In Brush's *Determinative Mineralogy* is found a method which, at least in inexperienced hands, has given better results, *i. e.*, fusion of the substance to be tested with sodium carbonate on charcoal in the reducing flame. The solution in hydrochloric acid of the bead thus obtained, boiled with tin or zinc, gives the characteristic violet color; but when the mineral contains less than four per cent. of titanium oxide, long boiling and consequent concentration is necessary. In fact the test would seem to be much less delicate than is generally supposed.

In the course of some analyses I quite accidentally found that a peculiar color is given to turmeric paper by solutions of titanium chloride. This color is hard to describe, being modified by the quantity of ferric chloride present in the solution; but it is neither the orange of zirconia nor the red of boron. It is rather a dull shade of purple, and is easily recognized when the paper is dried, although the color fades in a few hours.

By this means a solution containing .015 per cent. of titanium oxide can easily be tested. The same solution, treated with tin, required to be concentrated to one-tenth its bulk before a decided color could be obtained.

The color given to turmeric paper is intensified after the solution has been treated with tin. This and some other indications show that the best shade of color is given by the titanous chloride rather than by the titanic chloride, and no other salt of titanium than the chloride has been found to give the color.

Another peculiar property of titanium salts has come under my observation. When titaniferous minerals are soluble in nitric acid, and the solution is subjected to the action of the battery, the soluble titanium salt is converted into the insoluble oxide and appears on the electrode, in some cases, as a white coating; this

coating interferes with the estimation of copper, as it is deposited along with the metal.

In the absence of nitric acid it was found that a strong battery current reduced the titanic to titanous form under three different conditions, namely, in aqueous solution, obtained by fusion with potassium hydrogen sulphate, and in acid solutions of titanium oxalate and titanium sulphate. The oxalate, in particular, soon became a deep golden yellow, and after thirty-six hours, although the solution was clear, the addition of ammonia produced a precipitate of a beautiful deep blue color.

SILVER MILLING IN ARIZONA.

BY W. LAWRENCE AUSTIN, PH.D., CHARLESTON, ARIZONA.

It has been suggested to me that some data, bearing on the treatment of silver ores in Southern Arizona, would be in accord with the objects of the present meeting. I have, therefore, made a few notes, gathered from practical experience at some of the best known works of that district. Presuming the general arrangement of a silver mill to be familiar to members, the subject having been repeatedly brought to the notice of the Institute, it is my aim in the following description of the modus operandi at the different mills to which I would invite your attention, to give simply such salient points of the apparatus as have a direct bearing upon results, together with the cost of materials, labor, etc. I have gone somewhat deeply into detail in my descriptions of machinery, thinking that possibly some of our members engaged in this branch of the profession might find something of interest among them. In an industry such as silver milling, where the various works are scattered over a vast extent of territory, and the conditions under which results are obtained are subject to the greatest variations, it is essential to go into rather minute details in describing plants, processes, etc., in order to afford a clear idea of the operations. Not only should results be given, but also the means by which such are attained. The mineralogical and chemical constituents of the ore, and its physical properties, throw a flood of light upon the success or failure of a process. Figures representing totals I have subdivided as much as possible, so that the cost per ton for labor, castings, chemicals, etc., are apparent. Unless all these factors are known, no accurate comparison can be drawn, since in this branch of metallurgy, more perhaps than in others, the weakness of any one link in the chain of operations demoralizes the remainder. That it costs $10 to mill in one

locality, and $5 in another, is, in itself, no criterion of the quality of work done. But when these costs are referred to a standard, or when several mills are working on the same character of ore in the same district, and the conditions are known, losses, errors, etc., may be easily detected and remedied. As a standard, the conditions existing in any district can be taken. The cheapness with which the ores of the precious metals have been treated of late years in remote portions of our Western Territories is remarkable. The handling of very low grade ores has been made possible, and the cost of beneficiating the same has been reduced to figures that will permit of working ore bodies which, only a few years ago, were excluded from the category of paying investments.

The Harshaw Mill.

The mill of the Harshaw Mining Company, situated in the pleasant little mining town of the same name, in the midst of the Patagonia Mountains, Southern Arizona, recently completed its first working year, after a twelvemonth of uninterrupted operation. The results attained reflect credit on the management, when the high price which labor commands in that remote quarter, and the distance from sources of supplies are considered. At that time the nearest railroad station was Pantano, on the Southern Pacific, so that all material for the mines and mill had to be hauled by wagons, more than sixty miles, over a road that, in the rainy season, was almost impassable for heavy freight. The surrounding country is well wooded, mesquite, scrub-oak, and juniper all being found within easy access of the mill. The supply of water, however, is limited. I am indebted to Mr. Covington Johnson, the late superintendent, for the opportunity of examining in detail the workings of the system in use at Harshaw. The ore of the Hermosa Mine, which alone is treated in this mill, is typically "free milling." Horn silver, green when first taken out, but darkening in color when exposed for any length of time, is scattered through a gangue consisting of decomposed fragments, apparently broken from the inclosing porphyritic wall rock, in which quartz, clay, hydrated oxide of iron, and black oxide of manganese are prominent features. It is readily friable, the stamps crushing an average of five tons per head in twenty-four hours, and occasionally as high as six tons have been run through.

The ore is hauled from the mine to the mill down a heavy grade of something under a mile, by contractors, at a cost of fifty cents per ton. It is weighed at the mill—the weigher's wages are $4 per day—

and dumped over coarse screens. These screens, commonly known as "grizzlies," are composed of round bars of iron, $1\frac{1}{2}$ inches in diameter, 14 feet long, spaced 2 inches apart, and inclined at an angle of thirty-two degrees. Rectangular bars set on edge are preferable to round bars, not being so liable to clog. Such screens are a material item of economy, where large amounts of ore are handled, for, when placed so that the wagons can be unloaded over them, the finer material is separated from that which requires crushing, and the larger pieces alone require further handling, since what passes through the bars falls through shoots directly into the ore bins. It seems superfluous to add that wherever the expensive labor of the West can be advantageously replaced by automatic contrivances it should be done, especially in the reduction of low-grade ores;—yet how often is this simple axiom ignored!

On the crusher floor the lump ore, rolling down over the screens, is fed into a rock-breaker of the "Eclipse" pattern, and reduced to pieces about the size of a hen's egg. This breaker is in operation ten hours a day, crushing in that time sufficient material, inclusive of that passing through the screens, to supply the stamps for twenty-four hours.

On the dump and around the crusher four or five Mexicans are employed—whose wages are from \$1.50 to \$2 per day.

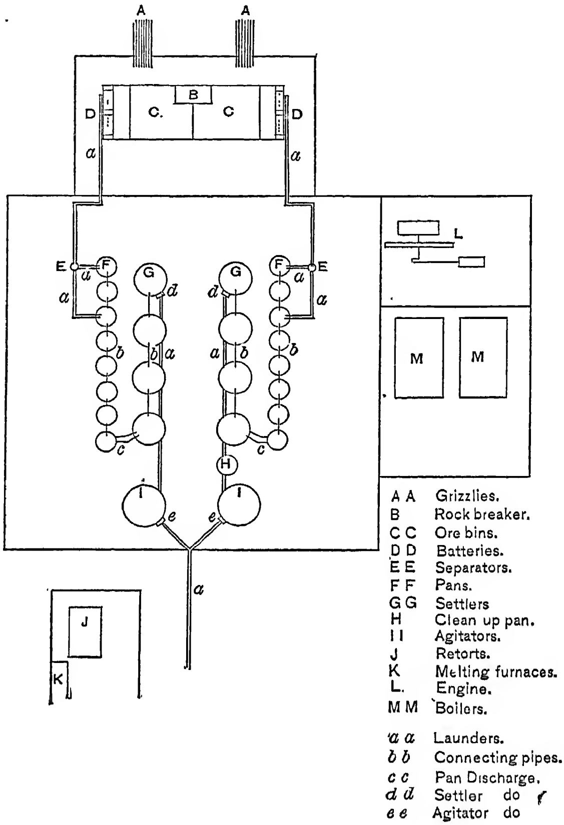
The ore bins, placed immediately below the crusher, have a capacity of 200 tons. In designing a mill it is always well to give such bins the greatest dimensions practicable, as they are often called upon to act as reservoirs in case of repairs being made on the rock-breaker, or of accidents at the mine or on the road. When possible they should be made to hold two or three days' supply of ore for the mill. From the bins the ore passes through shoots into automatic feeders which serve the stamps. Such shoots are quite short and provided with a gate to regulate the supply issuing from the bins.

The self-feeders are of the "Hendy-Challenge" pattern, and give perfect satisfaction. This mill was originally fitted out with the "Eclipse" feeders, but after a trial they were replaced by the present "Hendy."

The batteries are arranged back to back, as shown in the accompanying plan. Ten stamps are placed on either side, with the ore bins between them, the latter being built on to the battery frames, and the whole structure is thoroughly braced and bolted together.

Such an arrangement affords additional stability, and reduces in a measure that vibration which is so trying to the machinery, as well

as to the man whose duty it is to attend to this department; on the other hand its main drawback is that the "battery-feeder" is obliged to exert himself more than is otherwise the case in order to watch over both sides. The batteries are four in number, each of five stamps, crush wet, and have an average capacity of 5 tons to the



head. They are served by two men—wages $4.50 per day—each of whom stands a twelve-hour shift.

The stamps weigh over 800 pounds, the weight being divided as follows:

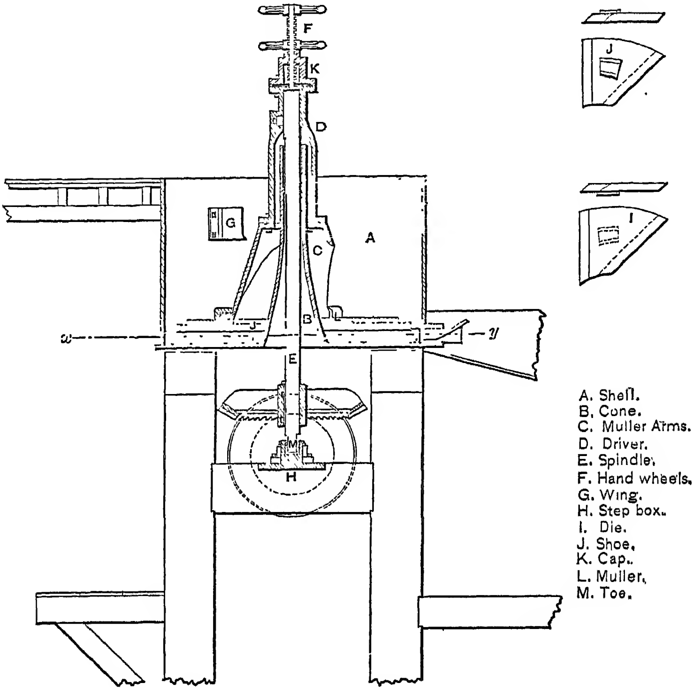
Stem,	405 pounds.
Shoe,	122 "
Head,	200 "
Tappet,	110 "
Total,	837 "

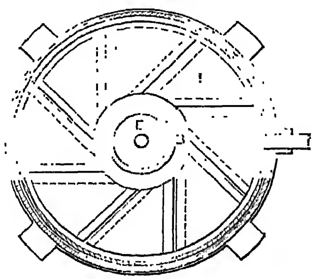
They are run at ninety drops per minute, and fall 6 inches. A reater drop was experimented with, but it was found that the heavy tamps crushed through the light material and expended the addiional force acquired to the detriment of the wearing parts and morar. The stems are 14 feet long, and $3\frac{1}{4}$ inches in diameter, with $\frac{1}{2}$ inches between centres. The shoes are of white iron, and last on n average eighty days. The dies, which are of the same material, veigh 107 pounds. Ten double-armed cams, with a sweep of 35 nches, are keyed on to a cam shaft 15 feet long and 6 inches in diamter, which has three bearings, each of $13\frac{1}{2}$ inches. The stamp-heads re of tough cast iron, with wrought-iron bands, shrunk on at bottom nd top, but in this case the bands used are too heavy, leaving only small ring of cast iron intervening between the shank of the shoe nd the band, which has a contrary effect to that desired, and weakens ather than strengthens the head. The discharge from the mortars s single, 11 inches high, through a number three vertically slotted creen of sheet iron. The actual discharging surface, deducting that overed by the wooden framing, is 479 square inches. The slots are inch long and $\frac{1}{32}$ of an inch wide. There are 9.6 of these slots to the quare inch of screen surface. The top of the screen is inclined outvard 10° from the perpendicular. The mortars are 50 inches long, nside measurement, and are provided with a double discharge, but it vas found advisable to stop up the rear opening, partly owing to lack f water, partly because when a single discharge is used the screens re less liable to become stopped up. This was accomplished by locking up with woodwork quite close to the stamp-heads, facing he whole with $\frac{1}{2}$-inch iron to prevent rapid wearing away. The loser the iron plate is brought to the stamps the better are the reults obtained. By this means the splash caused by the falling stamps s thrown forcibly forward, the screens are kept clear, and the disharge is increased. While both discharges were open, the rear one assed more material than the other.

From the batteries the pulp runs through launders to a separating opper,* in which the coarse sand is separated from that already ufficiently fine for amalgamation. This apparatus is a simple funel, with a partition at the side, so arranged as to direct the stream f pulp downward, and allow the sand to settle and discharge from the ottom, while the finer material rising on the other side of the partiion passes through an overflow and launder into the pans. The and is run into separate pans. Each line of pans is connected

* Described in Engineering and Mining Journal, xxxi., 179.

throughout by piping, placed 7 inches below their tops, which allows the pulp to flow on uninterruptedly, every pan in turn being filled, discharging into the next. The sand which is carried from the bottom of the separator into the first pan of the series is ground in that





SECTION THROUGH $x.y$

and in the next following, and joins the lighter material coming from the overflow of the separator in pan number three. By this means all tank shovelling is obviated, the pulp being brought into the amalgamating pans in fit condition for treatment with quicksilver.

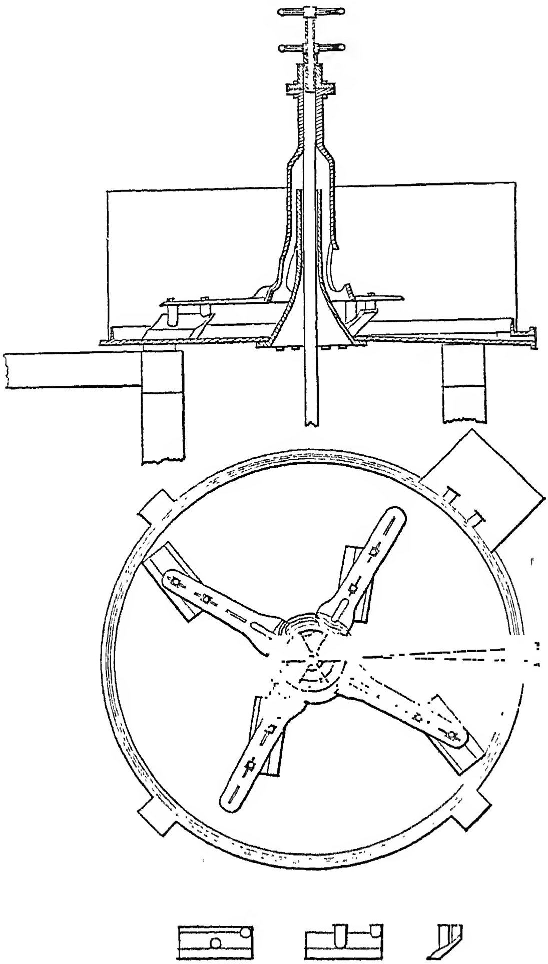
It has not as yet been satisfactorily proven that all milling ores wi equally well admit of this easy solution of the tank difficulty, bu where it can be used, the large saving in time and money to be gaine by this simple expedient is apparent. In the case under considera tion, the ore being entirely free from "base," and the gangue havin a light specific weight, the conditions are very favorable for thi method of treatment.*

The amalgamation is attended to by two amalgamators—wages $ per day, and by two helpers, wages $4 per day—working twelve hour shifts. The pans are of the ordinary flat-bottomed "combina tion" type, as shown in the accompanying sketch. They are 5 feet i diameter, 3 feet 4 inches high, have cast-iron sides, and taper up fror the bottom. The mullers make sixty-eight revolutions per minute, an are lowered in the first five pans of the series. As the pulp proceed down the line, and is subjected to the grinding action, the wear of th shoes and dies is lessened in each succeeding pan. There are eigh shoes and eight dies to a set, weighing 1504 pounds. In the first tw pans, where most of the grinding is done, the life of a set varies fror thirteen to eighteen days, whereas in No. 5 pan they last severa months. In the last three pans the mullers are raised and only serv as stirrers. The pulp is heated to a scalding temperature by liv steam introduced directly from the boilers. It requires about fou hours for the pulp to pass through the eight pans, and 200 pounc of fresh quicksilver are charged into each of the last six pans ever hour, the old charge being previously drawn off into settlers throug inverted siphons, which are closed before the introduction of the nev The greater part of the amalgam accumulates in No. 3 pan, whic is cleaned out every morning. Some amalgam always manages t work back into the first two pans, and is there found in the monthl clean up, although no quicksilver whatever is introduced into then Some experiments were made to determine whether or not the ama gamation could be conducted cold, and it was found that the ama gam, instead of accumulating in any one pan as before, was prett evenly distributed throughout them all. This illustrates the pa which heat plays in amalgamation, for, although the percenta worked to was in both cases about the same, still the time which was necessary to keep the pulp in contact with quicksilver is great increased when steam is not used.

The settlers are placed in the usual manner below the pans, one

* Since writing the above I am informed that this process is working equal well on heavy sands at the mill of the "Minas Prietas Mining Company" of Sono

every pair of the latter. Like the pans they are constructed entirely of iron, 8 feet in diameter, 3 feet deep, and make thirteen revolu-



tions per minute. The shoes, as shown in the accompanying sketch, are placed so as to throw the pulp downward, and at the same time toward the centre. They are four in number, one on each arm, and are raised a quarter of an inch from the bottom. As the pulp is already quite thin, very little clear water is used to dilute it further, but the temperature is considerably lowered by passing cold water through a spiral pipe attached to the sides of the first settler. The settlers are connected in a similar manner to the pans, but in their

case the piping is given a down grade, so that the end settler is never more than half full.

The tailings after leaving the settlers fall into wooden agitators, which make twenty revolutions per minute, and are shovelled out once a month. From them the tailings run to waste, carrying an average value of $4 per ton.

Only small quantities of chemicals are used in the pans,—a little cyanide of potassium, with a view of cleansing the quicksilver, and some caustic lime to collect any that may become floured. These are fed into the pans automatically, the cyanide of potassium into No. 3, and the lime into No. 7. Altogether only 14 pounds of the cyanide and 120 pounds of lime are used to 100 tons of ore. In order to determine how much lime is to be added, a dipper full of the pulp is taken from No. 8 pan and washed with a gentle stream of clear water, until only the quicksilver remains. This is usually in the form of small globules. If, on gently shaking, these readily unite, all is well, but should they refuse to do so, it shows that not enough lime has been used. Owing to the entire freedom of the ore from "bases" of any nature, the amalgam produced is remarkably clean; still a portion of the iron from the wear of shoes and dies finds its way into the amalgam, but it is easily gotten rid of in the "clean-up" pan. It usually requires four hours to clean up a charge of amalgam. About 1000 pounds is put into the pan and thinned with fresh quicksilver, then heated by live steam and stirred for a couple of hours. The impurities rising to the surface are wiped off with a sponge, and about equal quantities of salt and sulphuric acid are thrown in, and the whole is stirred for an hour. No difference in the appearance of the amalgam is effected by these chemicals, but on the addition of caustic lime a black scum immediately makes its appearance. This is washed off by allowing a current of clear water to flow through the pan. The amalgam is then taken out and piled on straining sacks.

The retorting and melting is carried on in a separate building. One man attends to both—wages $5 per day. The retorts are five feet three inches long over all, one foot in inside diameter, and weigh 1170 pounds. They have a central discharge; and when full hold 800 pounds of amalgam. A cord of scrub oak suffices for retorting seven or eight charges. The firing lasts about five hours, the amalgam retorting to one-sixth.

The furnaces for melting the retorted bullion are 15″ x 16″, and 21″ deep, inside measurement. Eight bushels of a very inferior

charcoal are used for melting a bar of 2000 ounces. A No. 70 graphite crucible is used in this melting. The bullion averages .995 fine, or more. All quicksilver used in the mill is pumped up to the pans by the hydraulic pressure system, a pipe connecting the quicksilver reservoirs with the mud-drums of the boilers.

The motive power of the mill is furnished by a 200 horse-power engine—cylinders 42″ x 20″—run at sixty revolutions per minute. Two engineers are employed—wages $5 and $6 per day, respectively.

Four tubular boilers—15′ 6″ x 54″—carrying 85 pounds pressure supply the steam, and require sixteen cords of the assorted wood of the country per day. Three firemen—wages $3.50 per day—and two wood-passers—wages $2 per day—attend the boilers.

All the water used is pumped from the gulch below by two Cameron steam pumps (No. 6) through a 2″ pipe. The boiler which supplies these pumps requires eight cords of wood per week; two engineers—wages $4 per day—look after the pumps.

The cost of reducing a ton of ore at these works, estimated from a run of 2643 tons, was $3.12, but this does not include the hauling, stated above to cost fifty cents per ton, or the general office expenses. This amount is subdivided as follows:

COST PER TON OF ORE.

Labor,	$1.23
Supplies,	1.82
Assaying,	0.07
Total cost per ton,	$3.12

The cost of labor, per ton of ore, in the various departments is as follows:

Crushing,	$0.26
Amalgamation,	0.20
Power, pumps, and repairs,	0.40
Foreman, melter, etc.,	0.37
Total,	$1.23

COST OF MATERIALS PER TON OF ORE.

Quicksilver,	$0.42
Chemicals,	0.07
Castings,	0.29
Illumination and lubrication,	0.07
Fuel,	0.78
Supplies,	0.19
Total,	$1.82

The consumption of wood, per ton of ore, was 0.15 cord, and of quicksilver 0.96 pound.

The Mills at Charleston.

Most of the mills working the ores of the Tombstone district are distributed along the line of the San Pedro River, at an average distance of ten miles from the mines at Tombstone.

The works at Charleston, of which I am manager, are the property of the Tombstone Mill and Mining Company, and are under the general supervision of Professor John A. Church.

These mills were originally intended for dry crushing, and were provided with rotary dryers, automatic roasters, and all the necessary paraphernalia for a chloridizing roasting, as it was expected that the ore would become base as depth was obtained in the mines. But, contrary to expectation, the deposits retained their free milling qualities as they went down, and the furnaces were never brought into requisition. Upon ascertaining the true character of the ore under treatment it was decided to change the batteries to "wet crushers," in order to increase their capacity, which alterations injured the symmetry of the plant, and left it working at some disadvantage over what might have been had such a change been foreseen in the original designs.

The smaller of these mills (the Pioneer mill of the district), was originally built by the company as an experiment, and constructed with an eye to economy; a wise precaution, as many have learned to their cost who have anticipated developments in their mines by the construction of expensive reduction works. This mill was originally fitted with ten stamps, four pans, and two settlers, and run by a Leffel turbine, water being brought in a ditch from a dam about one mile up the river. Later, in order to increase the capacity, five stamps, two pans, and a settler were added. To run this additional plant up to the necessary speed required more power than the turbine could furnish, so an engine was purchased as an auxiliary. The second and larger mill was subsequently acquired by the company. As both mills run on ore from the same mines and the processes are identical, a sketch of one mill will suffice for both.

It is to be regretted that owing to the separation of the mills, consequent doubling of the pay-roll, and increased expenses from every source, the cost of milling given below will be scarcely a guide to what could be done with a properly arranged plant. I do not hesitate to say that with altered conditions a reduction of 20 per cent. per

ton in the cost of ore milled could be effected, the quality of the work remaining the same.

In the following hasty sketch reference is had to the larger mill alone. The power is furnished by a horizontal engine with Corliss bed and Meyers patent cut-off, making 70 strokes per minute. The cylinder is 16″ x 36″. This engine runs with remarkable smoothness, and is not shut down more than once in sixty days, and then only to afford an opportunity for cleaning out the boilers, in which, owing to the water used, a scale rapidly collects. These latter are tubular, 54″ x 16″, and carry steam from 90 to 100 pounds pressure. Farciot's patent pump and heater feeds them, pumping the water in at boiling-point. They consume on an average seven cords of mixed wood per day, costing $9 per cord; black oak, white oak, willow, and pine being used indiscriminately. All the water for the mill is pumped a vertical height of 100 feet by a No. 5 Knowles steam pump, placed 200 yards from the mill, which readily supplies more than is consumed. Steam is carried to this pump from the mill boilers. The ore is brought down from the mines, a distance of ten miles, in wagons. These wagons are connected in pairs, weighing about 5 tons; they carry 14 tons of ore between them, and are drawn by sixteen mules. This hauling is done by contractors at $3 per ton. The bottoms of these wagons consist of a series of pieces of plank, 6″ x 2″, laid crosswise, their ends resting on the framework of the wagon-bed, so that, when removed one at a time, they allow the ore to drop out, and permit a rapid and easy unloading. It requires on an average twenty minutes to unload a pair of wagons constructed on this plan, and, as they are filled at the mines from self-discharging shoots, the driver has little labor in loading and unloading.

The ore is wheeled in barrows from the dump to the crusher through which it all, coarse and fine, passes, no screens being provided. One of Hendy's breakers is used. The bottoms of the shoots leading from the breaker to the bins are, for a distance of 5 feet, made of ¼″ steel bars set ⅜″ apart, allowing all the finer materials to fall through on to a shaking screen hung below. This shaker is provided with the same screens that are used in the batteries, and separates that portion of the ore already sufficiently fine not to need crushing, which is sent direct to the pans. This relieves the batteries materially, and decreases the amount of "slimes." By this simple contrivance the capacity of the mill was increased 5 per cent., or more, the amount depending on the fineness of the ore, and also on its percentage of moisture.

The batteries are fed from the bins by the Hendy "Challenge" self-feeders, which here, as elsewhere in my experience, give entire satisfaction. The stamps are 20 in number, drop 100 times a minute, fall $6\frac{1}{2}''$, and when freshly shod weigh about 750 pounds; the weight being divided as follows:

Stem,	340	pounds.
Boss,	200	"
Tappet,	90	"
Shoe,	120	"

The die weighs about 85 pounds. Some of the stamps carry extra tappets, bringing their weight up to 800 pounds and over. The shoes have an average life of one month, and when worn out weigh about 35 pounds. A novel feature of these batteries is the arrangement of the guides; instead of being grooved to receive the stem, square recesses are cut into which wooden keys are fitted, so that the grain of the wood is parallel to the motion of the stem, instead of across it, as is usually the case. With such an arrangement the guide-boards themselves are subject to no wear, the keys being easily taken out and replaced. This plan might be advantageously adopted where light stems are in use which are liable to spring, and in such a condition saw out guide-boards very rapidly. But when stems of $3\frac{1}{4}''$–$3\frac{1}{2}''$ are used they present no advantages over the old plan. The mortars have double discharge, but the rear discharge has been blocked up with wood faced with iron plates, as close to the stamps as practicable. The average product of these batteries, during the first six months of the year, including stoppages, has been 2.9 tons of medium hard rock to the head of stamps, per day of 24 hours, crushed through a 30-mesh screen. Various screens have been tried, but the best results have been obtained from Russian iron screens, vertical slotted, with a burr on the inside.

From the batteries the pulp goes into settling tanks. The pans, eight in number, are flat-bottomed, 5 feet in diameter, 3 feet high, and have wooden sides of Oregon pine curbs, $2\frac{1}{2}$ inches thick. The die is a solid cast-iron ring $1\frac{1}{2}$ inches thick, weighing 750 pounds, and occupying most of the space between the cone and sides. It is fastened in with Portland cement. The muller, weighing 570 pounds, carries eight shoes weighing collectively 816 pounds. Each pan is provided with three wings shaped like a reversed ploughshare. The settlers are 9 feet in diameter with iron mullers shod with wooden shoes 6 inches high. On the average a ton and a half, dry weight, of sand and slime are put in a pan for a charge,

and the time required for amalgamation varies from three to five hours after charging the quicksilver. Repeated experiments have shown that little is gained by running the pans over four hours; the same ore, treated side by side under the same conditions in pans, running respectively on four and six hour charges, gave a gain of one per cent. in favor of the six hour charge, but this slight advantage did not compensate on low grade ores for the limited capacity of the pans. Tests made on pulp while undergoing amalgamation showed that one hour after charging quicksilver, 74.66 per cent. of the silver was already taken up, and that in the succeeding hours 76.26 per cent., 77.74 per cent. respectively, until the end of the fourth hour, when 81.04 per cent. was found to have been extracted.

After that period nothing material was gained by prolonging the operation. For a long time, owing to the excellent quality of the ore, no auxiliaries, other than steam and the iron of the pans themselves, were needed by the quicksilver to effect amalgamation. Identical results were obtained with or without the use of chemicals. Little by little a change crept in, the milling percentage sank, the bullion became less fine, and sulphurets of the base metals made their appearance in the ore. Tests made with a view of determining the aid to be derived from the use of bluestone and salt, showed that in an ore containing only 7 per cent. of its silver in the form of chloride, 87 per cent. of the silver present could be brought into combination with that element by the aid of these two "chemicals." The remaining 13 per cent. was apparently shut up in the base sulphurets and carbonates, and could not be chlorinated in the pans. The result of a series of experiments with these and other reagents led to the adoption of 150 per cent. of bluestone and 500 per cent. of salt, the amount of silver in the ore being taken as 100 per cent., and by this means the milling percentage was brought back to its former standing. Still the bullion resulting left much to be desired. The question then resolved itself into this, how to make fine bullion from very base ores, and at the same time to keep up a satisfactory milling percentage.

Three methods suggested themselves, namely, either to prevent the amalgamation of the base metals in the pans,* or if that proved impracticable, to eliminate them from the amalgam before retorting, or during the melting. Although several metals were taken up by the quicksilver, in varying quantities, and so found their way into the

* I am indebted to Mr. J. M. Adams, of San Francisco, for valuable suggestions in regard to the handling of ores containing lead in pan amalgamation.

bullion, still the only one that caused any serious trouble was lead, which was reduced by the action of the pans and amalgamated as readily as the silver itself. A noticeable feature in regard to the basing of this bullion was, that it became serious at the same time that wulfenite appeared in considerable quantities in the ore. Whether this mineral was the prime cause of the trouble I am not prepared to say; but we did not have the same difficulty when the percentage of lead was much higher in the ore, but in the form of cerussite or galena.

The ore was crushed through a screen corresponding to a 35-mesh wire cloth, and subsequently ground for one hour in the pans. By giving up the grinding in the pans, and by using finer screens in the batteries, but little of the lead was taken up;* and by the use of lime, etc., in cleaning the amalgam, as already described above, the bullion was brought up to .970 fine; the remaining base, being principally copper, resulting from the bluestone used, was not of sufficient importance to extract. The extraction of copper, even after it has been amalgamated, presents no difficulties, as has been successfully demonstrated on a working scale at the tailing mills on the Carson River.

The ores of the Tombstone district carry a varying amount of gold, which in some cases is visible; but in others it only makes its presence known by the assays. At Charleston it is not positively known in what form this metal occurs, as it is never visible. Assays for the first six months of this year show that only 43 per cent. of the total gold value of the ore was saved. This value, however, rarely reaches two dollars to the ton. The amalgam is retorted in 15-inch top-discharge retorts. About 4 cords of willow wood are consumed to the ton of amalgam. The firing lasts five hours, and the charge varies from a ton upward.

For bullion averaging .938 fine the loss by volatilization and skimming averages 7.55 per cent., and the time required averages three hours, twenty-one minutes. The average weight of the bars is 2711 ounces, which require 43 pounds of charcoal and 20 pounds of coke. The average cost of milling for the past five months has been $4.90 per ton. This amount was subdivided as follows:

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* The experience of a former management was very similar; when grinding was carried on two hours, the bullion sank to .200–.300 fine, and even lower. By crushing finer and not grinding at all, it rose in a day or so to .900 fine and over. By grinding one-half hour it was kept at .850 fine.

COST OF MILLING.

Fuel,	$1.05
Chemicals (including quicksilver),	0.77
Lubrication,	0.04
Illumination,	0.03
Castings,	0.33
Supplies,	0.16
Labor,	2.52
Total,	$4.90

COST OF LABOR IN REDUCING ONE TON OF ORE.*

Crushing,	$0.52
Amalgamation,	0.67
Power, pumps, etc.,	0.47
Foreman, etc.,	0.87
Tailings pit,	0.11
	$2.64

The loss in quicksilver to the ton of ore milled varies according to the grade and character of the ore, but averages about 1.3 pounds. About 0.11 cords of wood and 1200 gallons of water are consumed to the ton.

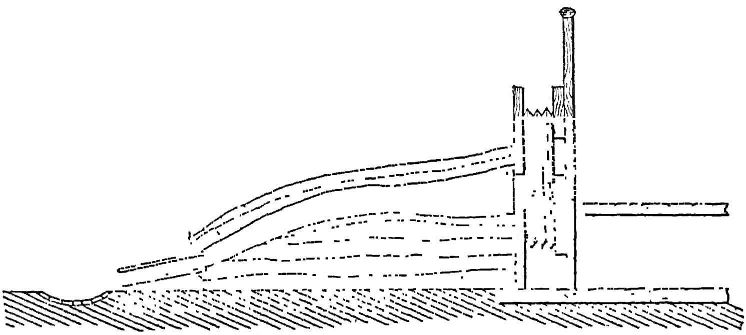
A NATIVE PROCESS OF SMELTING COPPER ORES IN THE STATE OF JALISCO, MEXICO.

BY WALTER B. DEVEREUX, E.M., GLOBE, ARIZONA.

METALLIC copper is a product of native metallurgy in various parts of Mexico, and by somewhat varied processes. While recently examining copper mines in the State of Jalisco, I had an opportunity of witnessing Mexican copper smelting by a process which I have not seen described, and which is interesting from the fact, that a fine quality of copper is produced from sulphurous ores in three metallurgical operations, and apparently without excessive loss. The process was carried on in buildings which were part of a plant erected by an American more than twenty-five years ago for the purpose of smelting and working copper. After a few years this man met with accidental death, and the works have been but little used since. Located in the centre of a high range of mountains, far from any town or seaport, and inaccessible except over difficult mule trails, these substantial buildings, filled with furnaces and heavy machinery,

* This table has reference simply to a single month's run, or, what is the same thing, to the working of 1730 tons of ore.

are a strange sight to be met with in one of the least advanced of Mexican mining regions. Under the same roof with English reverberatory furnaces and calciners, the crude Mexican furnaces yield a few small cakes as a daily product. The ore comes from a large vein not far distant, and consists of a quartzose gangue, containing about 5 per cent. of metallic copper in the form of copper pyrites (chalcopyrite). This is pounded by hand until it will pass through a sieve of raw-hide with ¼-inch holes. It is then subjected to a rude concentration in a trough through which water is flowing. The concentrated product yields, when smelted, about 30 per cent. of copper. It is first roasted in one of the old calciners in the works, although when necessary the Mexicans construct smaller furnaces, which answer the same purpose. After roasting, the ore is smelted in, or with, the furnace shown in the sketch, which constitutes the peculiar feature of the process. This furnace consists essentially of a pair of air-channels or long tuyeres, constructed in the top of a mass of crude masonry, with a bellows at one end, and what answers to a crucible at the other. In detail, these stone channels are about 7 feet long, slightly conical, and sufficiently raised at the back to allow free motion for the bellows. The fire ends are terminated by clay nozzles about 18 inches in length, and 2 inches in diameter at the outlet.



MEXICAN COPPER FURNACE

The ends of these nozzles come nearly to the edge of a circular basin, about 18 inches in diameter and 3 inches in depth at the centre. This basin is simply a depression in the earthen floor lined with the ashes of the *encino*, a species of oak. The ashes are rammed in moist, and then a smooth and true spherical surface is formed by a man stamping quickly around the basin with leather sandals on his feet. This basin is repaired, when necessary, in the same manner.

For each tuyere there is a round bellows about 3 feet in diameter,

which is attached directly against the stonework at the back. The construction is similar to that of an American round bellows. The back of the bellows is fastened to an upright frame, which is hinged at the bottom, near the floor, and is provided with a cross-piece at the top for a handle. Each bellows is worked by a single man, who stands on a raised platform, and takes a single step backward and forward at each blast. The blasts are given nearly alternately, and the two currents are directed by the nozzles toward the centre of the basin.

When smelting is to be commenced, a green pine pole, about 10 inches in diameter, is laid across the basin in front of the nozzles. The fire end of this is supported by a roller, so that it can be moved up easily. Pine charcoal is piled upon both sides of this over the basin, and plates of foul slag are laid across from the nozzles to the charcoal. By these contrivances a greater concentration of heat is obtained. When the fire is well lighted, ore is placed on that part of the charcoal outside of the log, and coal and ore are afterward added sufficiently fast to maintain the compact character of the pile. By this means the blast is prevented from breaking through with force and blowing the ore away. The blast is quite powerful, and the flames are constantly tinged with green. The *encino* makes a stronger coal than pine, and better for shaft furnaces, but it snaps too much for this process. By the time the ore has worked down to the bottom of the log, it seems to have agglutinated, and the melting copper and slag commence to drop at once. The whole of the smelting seems to take place before it settles into the basin, as after that the surface is almost constantly covered with charcoal. The log seems to be essential both for controlling the force of the blast, and for supporting the charge so that it is acted upon gradually, but with increasing power. When the basin is nearly full of slag the blast is stopped, and the coal scraped away. The slag is then removed in plates as it cools, the only implement being a round pole, which is slipped under the edge, and then carefully lifted up with the cake balanced upon it. If the cake of copper is not large enough, smelting is resumed, and when sufficient copper has accumulated, the slag is removed as before, the dust blown off with a bamboo tube, and the copper allowed to cool in the basin.

It is said that 300 pounds of ore can be smelted with one furnace in four hours, but I think that a considerably longer time is required. The cakes are made of 40 to 50 pounds weight.

The quartz gangue separated in concentration is used for flux.

The slags are very basic, but are well fused, and seem to contain little metallic copper.

It is interesting to note that, in the rude appliance described, we have all the principles involved in a shaft furnace; the gradual supply of ore and fuel, which gradually pass through increasing degrees of heat to a zone of fusion; the subsidence below into a receptacle where the metal and slag separate; the bellows and tuyeres; these are all the essentials. If in this furnace we simply remove the log, pile a few bricks around the basin, and cut an outlet at the bottom, we have at once a type which can, by simple amplification, develop into a complete shaft furnace.

The cakes of copper produced are soft, and seem quite pure. They are melted in a similar furnace once more, however, being treated precisely as the ore was treated, except that no slag is used. Scrap and refuse copper are added at the same time. There is no poling or stirring of the copper, the action of the heated charcoal being apparently all that is necessary to produce the proper pitch. This would indicate that oxide is formed during the melting down. No tests are made, in view of which the uniformity of the product seems remarkable. In honor of my visit a grimy old master smelter came down to superintend the finishing of a charge. Muffled to his ears in his *serape*, he did not even uncover his hands to grasp the pole with which he pushed the coal from the surface of the copper. A glance seemed to satisfy him, and, nodding to his assistants, he turned to me, and said with a very tragical air, *yo lo garantizo* (I guarantee it).

The cakes are made of the desired size, and allowed to cool in the basin until perfectly solid. Those intended for kettles are sold as they are, while those intended for sheets (about 125 pounds weight) are rolled in the mill of the old works. They seem to roll without flaws or cracks, and to produce an excellent product for sugar-pans and stills. This rolling-mill is a curiosity. The mill first sent out soon broke, and the American who inaugurated the enterprise recast the rolls and pinions of solid bronze of such strength that they are still efficient. He also constructed a set of Cornish rolls, every piece of which was of bronze. The consumption of charcoal in the above process is, I was told, nearly twice the weight of ore. The cost of coal delivered is about six dollars a ton.

In conclusion it may be pertinent to state that Mexico cannot now furnish a market for copper produced in any quantity. Foreign capitalists contemplating copper-smelting enterprises in Mexico, if wise, will base their calculations upon a foreign market for all their copper.

ON THE PECULIAR FEATURES OF THE BASSICK MINE.

BY L. R. GRABILL, QUERIDA, COLORADO.

THE Bassick mine, located six miles east of Silver Cliff, Colorado, has, ever since its discovery, been noted for peculiar features. Some of these characteristics exist in one or two other mines, while some are entirely unique.

Among these peculiarities I have selected the most noticeable for treatment in this paper:

First. The methods of deposition of the ores, which is not, as in ordinary veins, in strata or layers parallel to the walls of the fissure. The ores are arranged in concentric layers upon detached and abraded fragments of the walls; each ore in a separate stratum, and always in the same place in the series.

Second. The characteristics of the fissure or opening; its shape and dimensions; its contents, or the vein-filling; and its verticality.

Third. The peculiar products of the mine. The most noticeable of these products is charcoal, which is occasionally, and at long intervals, found throughout the ore-body, and in the surrounding conglomerate, from the surface down to the present depth, which is something over eight hundred feet. The existence of charcoal here is, as far as I know, the only instance of its discovery in mines of metallic ores.

Fourth. Besides the charcoal, there are other products, in themselves not peculiar, whose manner of arrangement and composition are unusual.

The mine is situated near the centre of a small rounded hill of eruptive trachytic rock and feldspathic conglomerate. The diameter of the base of this hill varies from 700 to 1200 feet, and its height is 200 feet above the general level.

A cliff or outcrop of fine conglomerate is exposed on the southwest side of the hill. On the northeast it joins by an upward slope the fine-grained, hardened feldspathic paste of Mount Tyndall, which rises 600 feet higher, and of which the elevation containing the Bassick mine thus forms an arm.

On visiting the mine, one's attention, whether he is a scientist or not, is immediately attracted by the unusual method of arrangement of the ore. It is seen to be disposed in concentric layers around fragments of trachyte. These fragments, of which each one con-

stitutes a nucleus for such a concentric arrangement, vary in size from boulders, having a diameter of sixty centimeters or more, to pebbles whose diameter is not greater than one centimeter. The sizes most common have diameters of ten to thirty centimeters. They have no sharp or rough edges or corners, but evidently have been much worn by water and friction before the deposit of the metalliferous minerals took place. The shape is often approximately spherical. They are formed of trachyte precisely similar in character to the country rock, and are, without doubt, a portion of it. When separated from the surrounding shells of ore, they rarely show by assay anything but a trace of precious metals. These, with their coatings of ore, quartz, and kaolin, constitute the greater part of the filling of the fissure. There is no barite, calcite, nor any one of the usual spars or crystalline alkali-earth minerals found in the deposit.

As previously stated, around each one of these waterworn fragments as a nucleus are arranged concentric shells of ore, each particular mineral being in a separate layer. The layers always follow each other in the same order, are of about the same proportionate thickness, and are all parallel to the surface of the nucleus. Usually three, sometimes four, distinct layers are seen, firmly joining each other in immediate contact, but with the line of separation perfectly plain.

The first stratum, next to the nucleus, and invariably the thinnest, is a compound of sulphur, zinc, antimony, and lead, consisting of the mixed sulphides of those metals. The shells of this stratum vary in thickness from the finest hair-line in the outer portion of the ore-body to sometimes 5 millimeters nearer the centre, but they are usually from ½ to 1 millimeter through. This stratum usually carries about 60 ounces of silver per ton, and from 1 to 3 ounces of gold; but varies much in composition and in thickness. It has a metallic lustre, a black color, hardness about 4, and is crystalline.

Next to this coating a second coating is often found, though it is not always distinctly to be observed, that is lighter in color, slightly thicker when apparent, and contains more lead, silver, and gold than the previous one. This coating frequently contains as high as 100 ounces of gold per ton, and 150 to 200 ounces of silver.

The third shell, counting from the nucleus outwards, is sphalerite. It is from 5 mm. to 5 cm. thick, with the mineral beautifully crystalline. It contains usually 60 to 120 ounces of silver per ton, and from 15 to 50 ounces of gold, and constitutes the principal source of

value in the mine. It shows also a considerable amount of iron, and some copper. Often it is the outside coating of the whole. The inner surface is smooth, but the outer is rough, with the points of the crystals projecting.

The fourth coating, when there is one, is formed of chalcopyrite. It varies much in quantity. Sometimes it consists merely of crystals, sparsely scattered over the rough pointed surface of the sphalerite; sometimes it attains a thickness of 1 or 2 centimeters. This carries as high as 50 to 100 ounces of gold per ton, and about the same amount of silver.

Outside of this is occasionally, though rarely, a fifth thin coating or sprinkling of pyrite crystals.

Surrounding all, especially where the larger interstices occur, but not usually among the smaller pebbles near the outer edges of the ore-body, is found kaolin. This exists, however, not as a coating, but rather to complete the filling of the crevices formed between the boulders.

The fragments of rock which these shells surround, are not necessarily in close contact, nor do they fit into each other in any way, as the pieces of a seamed or shattered mass might do; they resemble in arrangement and in general disposition something like a loose pile of waterworn stones which have been carelessly thrown into a heap, or into a pit (if that is better), and have afterwards been coated with their precious coverings. But one most peculiar fact regarding this deposit, and one which I am at much loss to explain, is, that the nuclei or barren fragments are rarely tangent to each other, while the shells surrounding them *are* so tangent. Thus, where we should reasonably expect to find actual contact between the boulders themselves, we frequently find instead, at the point of approximate contact, two separate shells of ore between them, one belonging to each nucleus; thus showing, that although the similar coatings on different nuclei must have been deposited at the same time, the fragments could not at that time have been in contact. What supported them during the period when the coating was taking place seems to be as much of a mystery as was to the ancients the base on which Atlas stood.

The only other mine with which I am familiar which has this concentric arrangement of minerals around a barren nucleus is the Bull-Domingo—only seven miles from the Bassick. But there the ores and country rock are different; it having galenite and then siderite deposited on a nucleus of syenite; and practically the ores contain no gold.

The fissure, which in itself constitutes one of the first peculiarities of the mine, is an irregular opening, nearly elliptical in horizontal section, but varying in diameter; the shortest distance across it is sometimes as low as twenty to thirty feet, and the greatest is nearly one hundred. It has been found that for over eight hundred feet its downward direction approaches the vertical very closely, though it winds slightly. It has, in horizontal direction, no defined termination. There are not, as in ordinary fissures, any signs of a wall of country rock, nor even a change from the character of the rock found filling the fissure, except as it shows less the marks of decomposition by solutions. There have been found no continuations or "extensions" of the ore-body or of the fissure; though such have been carefully sought for, and it has often been claimed they have been discovered. Ever since the mine was first opened, some defined limit which might be termed a wall, or at least a definite boundary to the fissure, has been the object of much exploration, but no such thing has been discovered. It is true, of course, that there is a limit to the "pay" of the ore-body, and this has determined a limit of working.

The ore is richer nearer the centre of the body, the layers or shells called "scales" in the vocabulary of the mine, being thicker there and containing a larger proportion of the precious metals; but, as the edge is approached, it "thins out," and gradually becomes poorer, until at last it is too poor to work. The sphalerite scale predominates in the middle of the body; while further out we find only the thin and poor first shell. The size of the rounded and polished fragments of porphyry, which are the principal filling of the fissure, is also greater near the centre of the opening. This leaves, of course, larger interstices, in which the larger combs could be formed.

The scales of ore decrease in thickness as the distance from the centre of the opening increases. The character of the ore changes in some degree as the shells become thinner and the pebbles smaller. Continuing our course outward, at last we merge, without having passed any particular line marking a boundary, into a conglomerate composed of the small rounded pebbles of feldspathic rock, cemented by a hardened trachytic paste, but containing no ore-shells. This conglomerate shows at first, after no more scales of ore can be discovered by the eye, traces of the precious metals; but finally, still further from the centre, none. The limit of the pay is thus practically determined by assay,—that being removed which will pay for

concentration, while that is left which will not do so. It is of course only possible to determine this by repeated tests.

Again, in the same manner, without finding any special defined boundary to this conglomerate, we merge into the country rock. This is of the same feldspathic nature, gray in color, and eruptive; but it is not a conglomerate. This country rock is the same on all sides of the ore-body. There is no different rock apparent on the surface or discovered by any drifts. There is no sign of any contact in the immediate vicinity; no signs of an extended fissure. The contact between the rhyolitic granite of the surrounding region and the eruptive rocks is from one-quarter to one-half of a mile distant; but has not been shown to have any connection with this opening.

A theory of the manner of deposition of this ore, based on these facts, and others, is difficult to arrive at, but would be somewhat as follows:

The present ore-deposit has been the scene of action of a mineral spring, or geyser carrying the minerals in solution in its waters; the whirling, flowing motion of the water, causing the fragments, which have been broken from the wall, and with which the fissure was nearly filled, to grind with much friction against each other, has rounded and polished those fragments; and afterward, at a different period, the ore has been deposited.

Another fact to be noticed is this: that the first and thinnest coating deposited is the same in all cases, and is found to be the inner coating of the large boulders as well as the sole covering of the smaller pebbles; being the antimonial and very impure sulphide of lead, already mentioned, sometimes resembling jamesonite. The fact that this scale is *always* present, while in the outer and more compact part of the deposit the sphalerite scale is nearly always absent, would seem to indicate this, viz., that, with the circumstances first favorable for the deposition of shell number one, this coating formed in the *smaller as well as the larger* crevices, and among the pebbles on the outer limits of the loose mass, and completely closed and filled most of the smaller crevices, preventing access of other solutions afterward, and thus preventing the subsequent deposit of sphalerite there.

Other products of the mine, quite noticeable, but occurring in smaller quantities than those already mentioned, are calamine, smithsonite, jamesonite, galenite, tetrahedrite, the tellurides of silver and gold (though the latter are in quantities so minute and so mixed with other ores that they can rarely be detected), free gold, quartz,

and charcoal. The calamine and smithsonite are found only among the upper or oxidized ores, above the water-level, and are of course the result of the decomposition of sphalerite and other combinations of zinc. Most of the free gold also is found above the water-level, in wires and other usual forms.

The tetrahedrite never occurs as a shell or coating, but always filling vacancies outside of the coated boulders, and is always found intermingled with quartz. It is impure, and small broken bits and portions of the first and second coatings are sometimes mixed with it and distinctly to be recognized, but never portions of the third or sphalerite layer. In the same mass also the tellurides of gold and silver are contained. The *whole* is, in the nomenclature in use at the Bassick, termed "tellurium." I am indebted to Professor Charles E. Wait, of the Missouri School of Mines and Metallurgy, at Rolla, Missouri, for the results of determinations of tellurium in two specimens. One gave him five one-hundredths of one per cent; the other gave eight one-hundredths. This ore contains from two hundred to three hundred ounces of gold per ton, and from one hundred to two hundred ounces of silver. It occurs granular, massive, noncrystalline. It is sometimes soft, but is often so siliceous as to be very hard.

The quartz in the mine seems to be wholly a residue from the decomposition of silicates by impregnating solutions, or by solutions from altered sulphides. It is found, like the tetrahedrite, occupying the open spaces outside of the coated boulders, and never within them; and it serves partly to act as a cement to hold the mass together. It appears in many singular shapes, resulting principally from the forms of the crevices in which it exists, such as those of bones of animals, sea-shells, and twigs and limbs of trees. The fancied resemblances have given rise to the idea that some pieces of the quartz are petrified remnants of animals and vegetables, but such is not the case. This quartz is mostly amorphous, rarely showing any traces of crystallization; when it does so it is amethystine. Often it appears to have been deposited in a gelatinous state. It ranges in color from pure opaline white through gray, blue, and brown shades to black.

But the most striking among all the features of the mine is the existence of charcoal. This is found in cavities between the coated boulders, and toward the outer edges of the ore-body, but is not necessarily adjacent to ore. It does not often occur, but has been found both near the surface and at great depth.

The last pocket of charcoal of which I am aware was discovered last winter at a depth of about 765 feet from the top. It was broken open by a blast, and was much disturbed and torn to pieces. There must have been, judging from the pieces I afterward saw, a space equal to a cube with an edge of 30 centimeters filled with charcoal. Other pockets of about the same size, and smaller ones, had been found previously. It was most common near the water-level or the base of the hill. The last appearance was not in the pay-ore proper, but was in the surrounding conglomerate, which was firmly attached to the outer portion of it, so that specimens could be obtained containing both the rock and the charcoal. The grain of the wood was distinct, showing the longitudinal fibres and in cross-section the circles indicating the growth. It was mostly soft and friable, easily soiling the hands, and having the texture and appearance of ordinary charcoal; but some of it was silicified to such an extent that it presented nearly the characteristics of very hard, black quartz. Nearly all of it had the pores filled with glittering crystals of pyrite, deposited there by infiltrating solutions. The softer portions of the coal will glow and finally burn under the blowpipe; but the siliceous parts remain nearly unaffected. I have one specimen of this coal which shows distinctly the circular cross-section of the trunk or branch of a tree some 4 or 5 centimeters in diameter, while attached to this are both barren porphyry and rich ore. The section is from 3 to 4 centimeters long. Part of the rings in the charcoal have been replaced by rings of crystallized minerals. This specimen is from the upper levels of the mine, and consequently shows the oxidized ore. Pieces containing quartz, porphyry, and ore often appear.

It might be possible, by the use of the microscope, to determine, from the exposed grain of the charcoal, the nature of the wood from which it is formed, but this must be left to the botanist.

The appearance of this coal, at a depth of eight hundred feet, in eruptive, unstratified rock, is almost phenomenal. It will doubtless continue to be found still further down, as the sinking of the mine progresses. Although the surrounding rock is a conglomerate, there are no indications, except the coal, that it was ever on the surface; besides, the occurrence of coal at various depths would upset that line of argument. How a piece of wood could have ever made its solitary way to this distance *below* the surface, there to become charred, and afterward to be uncovered by the dauntless miner in his search for gold, is one of those mysteries which Nature is continually presenting for our solution. Perhaps it might be explained by the theory

that on the borders of the hypothetical spring or geyser grew plants and trees; and that rocks on the edges, caving and falling in because undermined by the water, carried with them into the depths and buried there, the plants which were by heat and pressure converted into charcoal.

I have mentioned only those among the most distinctive characteristics of the mine. Many other peculiarities are noticeable—in fact, scarcely anything reminds one of the ordinary construction or arrangement of an ore-deposit. The mine is well worth the examination and study of the scientist and mining engineer.

DISCUSSION.

MR. R. NEILSON CLARK, Leadville, Col.: I wish to refer to one matter of interest,—the charcoal that is found in the Bassick mine. It is found at great depths, and it is a true charcoal,—there is no question about that. It is not a lignite, nor anything else that looks like charcoal without being so. As a rule, around these pieces of charcoal are found the rich bodies of ore.

As to the cores around which the shells of ore occur, they are angular, are they not, Dr. Munson?

DR. GEORGE C. MUNSON, Milford, Conn.: They are angular, but with the *sharp* edges worn off.

PRESIDENT ROTHWELL, New York City: The appearance of charcoal is somewhat deceptive in mines. For example, in the anthracite mines of Pennsylvania we occasionally find between the layers of anthracite thin seams of a substance that exactly resembles common charcoal. In the anthracite regions this substance is called "mother of coal," for what reason I do not know. In physical structure it is exactly like charcoal; traces of the fibre of the wood can be seen in it; and in every other respect it is scarcely to be distinguished from charcoal.

Charcoal has also been found in the silver-bearing sandstones of Southern Utah. These sandstones are a simple sedimentary formation, and contain trunks of trees, some finely silicified, twenty, thirty, or even forty feet in length, with the bark and leaves plainly discernible. The trunks are found disseminated through the bed, just as they fell, or, in some cases, standing upright. I have also found there pieces of lignite with the structure of the wood still quite evident and the bark quite perfect; even the fruit of the tree, the nuts, could be distinctly recognized. Other portions of the carbonaceous

matter have almost the character of charcoal; the carbon has not become hard, nor taken on the form of lignite. The woody fibre of ordinary charcoal can be traced in it very clearly. Even in the silicified woods the carbon has not entirely disappeared; it has something of the character of coal dirt. In the silver-bearing portions of these beds, the charcoal, the lignite, or the silicified wood, as the case may be, is impregnated with chlorides or sulphides of silver, and is, in many cases, quite rich. I have pieces that the assayer told me would run from forty to fifty dollars a ton. The charcoal of the Bassick mine I have never seen; this is the first time I ever heard of it. But it reminds me of the occurrence of carbonaceous matter in the form of charcoal and lignite, or in connection with silicified tree-trunks at the Silver Reef mine in Utah, though in structure the two deposits do not resemble each other in the least.

The Bassick ore has still another resemblance to ores found in Utah. At the carbonate mines in the Frisco district, not very far from the Horn Silver mine, there is a fissure in porphyry,—a trachytic porphyry, I believe, but at all events clearly a porphyry The fissure is well-defined and cuts across the porphyry, at a long distance from the quartzite. It has apparently been enlarged by the decomposition of the walls. Pieces of the walls have fallen into the fissure, and, as is generally the case with eruptive rocks, the angles have peeled off and given the pieces a more or less spherical form. These little balls of porphyry, varying in size from quite small pebbles to boulders of considerable size, lie apparently loose in the fissure and are surrounded with concentric layers of galena and, in most cases, blende. These balls I have taken out of the mine at a considerable depth, 150 or 200 feet, if I remember rightly. They were lying in the bottom of the mine, where the vein was wet, in a mass of decomposed porphyry so soft and muddy that it could be scraped up by the hand. These balls of porphyry, surrounded by galena, were scattered quite loosely through the mass, though some of them were cemented together where the coating had become thick enough to unite balls that were near each other. The character of the ore, too, seems to be remarkably similar to that of the Bassick mine, notwithstanding the difference in the deposits. The concentric scales are small and consist mainly of galena. The fissure is straight and well-defined, not at all resembling a geyser or an overflow of the character cited in the paper read to account for the peculiarities of the Bassick mine, and it is known to exist for a considerable distance. Openings have been made upon it at several points

and shafts have been sunk in it to a considerable depth; but the ore-body, of course, is not continuous.

Mr. Charles A. Ashburner, Philadelphia: I would like to say a word with reference to the occurrence of charcoal in the anthracite regions of Pennsylvania. So far as I have seen, there are very few instances of its occurrence. The charcoal, or substance resembling charcoal, is generally found in the bony coal or slate beds which lie between the purer seams of coal. It has occurred to me that probably the original vegetation from which this was formed was protected by the argillaceous material during the time the regular seam was changing from wood to coal, and that the charring of the wood and its conversion into a substance resembling charcoal were the result of the heat that accompanied the change.

Mr. Henry M. Howe, Boston, Mass.: When I was in Canada, I saw a large vertical deposit of galena, sixty or eighty feet across, that was about a tenth or an eighth part filled with fragments of country rock. The country rock was a rather fine-grained porphyry. The fragments met with in the deposit were apparently as sharp on the edges as when they were broken off from the walls. The spaces between them were filled with calcite, whose structure pointed to an aqueous origin, and coarsely crystalline galena. In sharpness of edge these fragments resembled those found in the Bassick mine, but they were so far apart as to make it impossible to believe that they ever rested one on another, and it is quite impossible that they were held in suspension in the solution from which the calcite was deposited. I would suggest, as a possible solution of the difficulty, that there may have been an eruption of igneous matter, the intrusive masses solidifying sufficiently rapidly to hold the sharp fragments in place, and being afterwards replaced by the deposit of calcite.

Dr. R. W. Raymond, New York City: In connection with the occurrence of charcoal at unusual depths, we are reminded of the comparative indestructibility of charcoal. Instead of being surprised that we occasionally find it under these circumstances, might we not be surprised that we do not find it oftener? When once inclosed in the rock or the rock-forming material, and protected from air and from actual mechanical operations, there are very few agencies which would be likely to alter it in the least. In Oregon I have seen, between the successive overflows of lava, very thin layers of mud, in which, with lava both below and above, the most delicate vegetable remains are found, including leaves, buds, and twigs of the finest texture. The power that lava has of preserving

without injury is sometimes strikingly shown in such ways. In our blast-furnace practice, there is no more obstinate scaffold than one formed chiefly of coal. The reducing power of organic carbon (and hydrogen), when the conditions are favorable, may have been an important factor in ore-deposition. Some years ago, I went into an old adit (supposed to have been driven by the Spaniards) in the Cerillos range, New Mexico. Lying in the bottom, and exposed to the mine waters, was the wreck of an ancient pick-axe. The handle had apparently decayed and been washed away. At all events, no trace of it remained; but the eye-hole was filled with beautifully crystallized galena. I suppose this was a case of reduction from sulphate of lead through the agency of the decaying wood. No other part of the iron pick showed any deposition of galena.

Mr. George W. Maynard, New York City: The occurrence of charcoal and lignites in mines is by no means rare. At a previous meeting of the Institute I called the attention of the members to the occurrence of lignitic masses in the Permian sandstones of Russia, and I have also seen the same in Southern Utah. As to the indestructibility of charcoal, I recollect that very frequently pieces of unconsumed charcoal, that had been charged into a blast furnace with the ores used in the manufacture of pig-iron, have been found imbedded in the cinder, after sinking forty or fifty feet through the furnace.

COMPARISON OF VARIOUS METHODS OF COPPER ANALYSIS.

BY W. E. C. EUSTIS, BOSTON, MASS.

During the last year I had occasion, on behalf of our New York copper works, to send to various chemists samples, intended to be accurate, of material which we were buying and selling, and I was astonished to find what differences were reported. After talking over the probable reasons for this with a number of chemists and metallurgists, it was suggested that it would be of real use and some scientific interest to send samples to the different chemists, and take such care in making up the samples that we could feel sure that each chemist had as nearly identical a sample as it was possible to make. After some consideration it was determined to send a mixture which should carry about 50 per cent. copper, and

have all the impurities which are ordinarily met with in a copper ore.

This mixture was chosen in preference to borings of pig copper, because I was unwilling to guarantee such borings to be identical. At Messrs. Pope, Cole, & Co.'s request, however, I subsequently sent out six samples of pig copper put up by them. With reference to this their experience coincided with my own, viz., that the differences in borings were greater than in any other samples; the explanation of which, I think, is easy. Borings of pig copper are, or should be, taken by drilling through the pig from top to bottom; the top and bottom, being a mixture of slag and oxides, come out in form of powder, while the inside, being malleable copper, comes out in strings. The chemist receives a bottle of borings as a sample, weighing perhaps from 70 to 150 grams. Of this amount he selects from 1 to 10 grams for analysis. From actual analysis of some average borings I found the fine portion to assay about 20 per cent., while the inner borings assayed 99.5 per cent. As the borings cannot be crushed, the difficulty of getting a correct sample is apparent. Mr. William Glenn's method of accomplishing this commends itself, and although it may be common, I will mention it. It is simply to operate on the borings in the bottle with a pair of scissors till the large borings are all chopped up; he then goes on in the ordinary way by quartering.

The material sent to be analyzed consisted of the following:

White metal, containing some metallic Cu, about	75 per cent. Cu,	1650 grms.
Cement copper, ...	85 " "	1040 "
Foul slag, ...	3 " "	900 "
Milan sulphuret ore, containing 10 to 20 p. ct. Zn,	1 " "	900 "
Arsenious oxide (As_2O_3), ...		50 "
Sulphate of nickel ($NiSO_4$), ...		30 "
Total, ...		4570 "

The sample was put up in my laboratory by Mr. Faunce, in presence of Prof. R. H. Richards and myself. After a thorough mixing, the stuff, about a half inch thick, was spread out on a paper, and divided into about 25 squares. The boxes sent out were filled by taking a little from each square; with this sample Professor Richards expresses himself as being entirely satisfied in the following statement:

CALUMET, August 5th, 1882.

About the end of May, 1882, I witnessed in the office of Mr. W. E. C. Eustis, of Boston, the preparation from some copper products

of a test sample which was prepared to ascertain to what extent the results of different assayers would vary from each other when tried upon the same sample.

The ingredients, which had been put through a fine sieve (not coarser than 60 meshes to the linear inch), and which contained copper, nickel, iron, zinc, arsenic, sulphur, silica, etc., were thoroughly mixed for more than half an hour by rolling them industriously, right and left, forward and backward, in a large sheet of paper.

The sample was divided among some twenty-five small boxes as follows: It was flattened out on the paper, and two sets of parallel lines drawn on it in such a manner as to mark the whole surface into squares about $2\frac{1}{2}$ inches on a side. Each one of the boxes was then filled by taking a little ore from every one of the squares with a spatula. When the squares lost their form the surface was flattened out and again marked into squares, and the boxes filled as before. This operation was repeated until the boxes were all filled.

I consider the division of the samples among the boxes to have been as accurate and fair as it is practicable to get it.

ROBERT H. RICHARDS, S.B.,
Prof. of Mining, Mass. Inst. Technology.

Twenty-three samples were sent out, and the results returned are highly interesting, the lowest being 43.90 per cent., and the highest being 53.34 per cent., with the others ranging in between.

The results are given in the table on the following page:

Results of Analyses of Copper Ore.

Name.	Results.	Average	Methods.
Booth, Garrett, & Blair,	47.72	47.72	Electrolytic from $H_2SO_4 + HNO_3$ solution.
Dr. C. F. Chandler, .	47.14 46.94	47.04	Electrolytic from $H_2SO_4 + HNO_3$ solution.
W. H. Chandler, . . .	48.64 48.72	48.68	Electrolytic from H_2SO_4 solution.
A. Cochrane, ...	48.63 48.66	48.64	Precipitation on zinc in platinum dish.
Dr. T. Egleston, No. 1, " " No. 2, " " No. 3, " " No. 4,	47.25 47.02 47.07 47.05	47.25 47.05	Electrolytic, and weighed as Cu_2S. Electrolytic from HNO_3 solution. Electrolytic from HNO_3 solution. Electrolytic from $H_2SO_4 + HNO_3$ solution.
Dr. F. A. Genth, . .	47.16 47.06 46.87	47.03	Precipitation as CuS, roasting, dissolving in H_2SO_4, driving off acid by heat, and estimating as CuO.
Wm. Glenn, ...	46.84 46.91	46.87	Electrolytic from $H_2SO_4 + HNO_3$ solution.
W. M. Habirshaw, . .	43.90 43.92 47.07 47.17 47.28 47.26	43.91 47.12 47.27	Estimation as Cu_2S. Weighed as Cu_2S. Electrolytic.
R. R. Hedley, . . .	46.62 46.75	46.68	Volumetric by KCy.
F. F. Hunt, No. 1, . . " " No. 2, . .	46.73 46.68	46.70	Electrolytic from H_2SO_4 solution. Electrolytic from HNO_3 solution.
T. Kiddie, ...	46.24	46.24	Volumetric by KCy.
Mathey & Riotte, . .	53.34 53.09 53.34 51.82 50.94 50.87	 53.26 51.21	Volumetric by KCy. Swedish.
G. H. Nichols & Co., .	47.09 47.01 47.03 47.05	47.05	Electrolytic from $H_2SO_4 + HNO_3$ solution.
Pope, Cole & Co., . .	46.94 46.98	46.96	Electrolytic. Precipitation in platinum dish by pure zinc.
R. H. Richards, . . .	47.01 47.05	47.03	Electrolytic from HNO_3, with previous precipitation as CuS.
S. P. Sharples, . . .	47.97 48.15	48.06	Electrolytic from $H_2SO_4 + HNO_3$ solution.
Stillwell & Gladding, .	46.82 46.84	46.83	Electrolytic from HNO_3 solution.

I wish merely to point out two sources of error, which the chemists may have avoided, though most of them have not said so.

First. Of samples sent in boxes through the mail, no two will contain the same amount of moisture; therefore each chemist should have dried his sample before weighing, so that he could be able to refer back to the sample at 100° C.

Second. The sample contains about 0.1 per cent. silver. As most of the methods of electrolytic work are careful to keep out hydrochloric acid, considerable silver may be precipitated with the copper.

Contrary to my expectations, the analyses of the borings are, with one exception, much closer than you can, as a rule, count on getting. They are as follows:

Results of Analyses of Copper Borings.

Name.	Results.	Average	Methods.
Dr. T. Egleston, . . .	94.64 94.70	94.67	Electrolytic from HNO_3 solution.
Wm. Glenn, ...	94.92 94.81	94.86	Electrolytic from H_2SO_4 and HNO_3 solution.
W. M. Habirshaw, . .	91.07 91.10	91.09	Cu_2S in hydrogen gas.
	91.23 91.16	91.20	Electrolytic from HNO_3 solution.
T. Kiddie, ...	94.38 94.57	94.47	Volumetric by KCy.
G. H. Nichols & Co., .	94.62 94.64 94.60	94.62	Electrolytic from H_2SO_4 and HNO_3 solution.
Pope, Cole & Co., . .	94 85 94.91	94.88	Electrolytic. Precipitation in platinum dish by pure zinc
S. P. Sharples, . . .	98.17 97.97	98.07	Electrolytic from H_2SO_4 and HNO_3 solution.

One thing about precipitation by the battery and the consequent action of arsenic in solution:—I have found with sulphate and nitrate solutions, containing 50 per cent. arsenious oxide in solution, that no arsenic is precipitated as long as an insoluble anode is used, while with a soluble anode several per cent. are precipitated; so that it would seem that in ordinary battery analysis no precautions need be taken to get rid of the arsenic.

Again, I need hardly speak of the necessity, in the cyanide method,

of precipitating the copper first on iron or zinc to rid it of zinc, els zinc may be read as copper. I mention this fact, since it is so common to check the slags in furnace work by the simple color, and if there is much zinc present no idea can be formed what the slags do carry. Further, and most important of all in this method, great care should be taken to make sure that the copper by which the cyanide solution is standardized is pure copper precipitate. Buying electrolytic copper from the dealer does not necessarily give you pure copper. In fact, the probability is it is not pure.

Unquestionably, the copper should be first analyzed before standardizing, just as in assaying silver the lead has to be assayed also.

Another substance, bismuth, mentioned in the letter from Mr. Thomas B. Stillman, given below, is of interest as affecting copper analyses.

A batch of copper of a new brand was refined, and made very bad-looking copper. Borings were taken, and examined for the ordinary impurities, such as lead, zinc, arsenic, antimony, and silver, and they were found to be remarkably free from these substances; finally, bismuth was found in considerable quantities, and it was this, undoubtedly, which gave the copper the bad look.

The copper was subsequently used, and found to work well.

NEW YORK, August 11th, 1882.

JOHN L. THOMPSON, ESQ., Bergen Point, N. J.:

DEAR SIR: "I weaken." In other words, Mr. Kiddie's assay is right, and mine too high. My three first determinations, which gave me 97.02 wet, agreed very closely; and the first three I made on the samples you sent gave me 97.03, so that the work was close enough. I had decided to call it 97.02 and have a third party in when it occurred to me to precipitate the copper with zinc, filter, dissolve in HNO_3, evaporate, take up with H_2SO_4, and then use battery. This method brought me to where Mr. Kiddie was, 93.4 dry. So the excess of 2 per cent. I had before was due to metals brought down by the battery in acid solution, such as silver, bismuth, etc. This easily accounts for the difference.

Very truly yours,

THOMAS B. STILLMAN.

Appended are descriptions of the various methods used by the different chemists to obtain their results.

In closing, let me most heartily thank these gentlemen who have

so cordially co-operated with me, and let me join with them in hoping that some good may come out of it.

Description of Methods of Analysis Employed by the Different Chemists on the Samples of Ore.

Booth, Garrett & Blair.

Our method is: Digest 100 grams in HNO_3, evaporate to dryness on water-bath, redissolve in water, filter into a liter flask, the flask being filled to the mark, mix solution well, take two separate portions of 100 c.c. each, add a sufficient amount of H_2SO_4, evaporate until fumes of SO_3 appear and the mass is nearly dry, then redissolve in water, and precipitate on platinum cylinders by two cells of a Daniell's battery. After the precipitation, the cylinders are well washed in distilled water, then in alcohol, and dried quickly in water-oven before weighing. The ore, though well ground, has a tendency to separate into richer and poorer by handling, as may be seen in the different appearance of the insoluble matter left after digestion in HNO_3. Hence it is difficult to make two assays agree unless a large amount is dissolved and the solution divided. This will probably, in part, at least, account for the variation in the amounts of copper reported by different chemists.

Besides the above assays, we made four determinations of copper from *separately* weighed portions of the ore, and found them to vary from 46.76 to 47.20 per cent., thereby confirming our opinion in regard to the separation of the ore by handling.

Dr. C. F. Chandler.

The finely-pulverized ore was treated with fuming HNO_3, a little concentrated H_2SO_4 was added, and HNO_3 expelled by heat. The whole was then treated with water, filtered, and precipitated by the galvanic battery, a few drops of HNO_3 being added to the solution. The Cu was weighed as metal in the platinum dish in which it was deposited. In the first determination the residue, insoluble in acids, was fused with Na_2CO_3, and the precipitate was added to the main solution before the Cu was precipitated. In the second determination this step was omitted.

The work was done by Dr. Chandler's assistant, Dr. E. Waller.

Dr. W. H. Chandler.

The sample as received was thoroughly mixed, a small sample was taken and ground to a fine powder, and a portion was weighed

without previous drying. It was dissolved in aqua regia in a small beaker on the sand-bath, and, after an hour, dilute H_2SO_4 was added in slight excess, and the whole mass was evaporated until it became dry and gave off abundant H_2SO_4 fumes. After cooling, the mass was dissolved in water, filtered, and washed thoroughly. In the presence of much lead a *little* H_2SO_4 may be used in the wash water. In the presence of much iron there is danger that the $CuSO_4$ may remain with this in the filter. In the method pursued, the filtrate, obtained as above described, is evaporated to about 100 c.c., and if it contains much acid this is partially neutralized by Na_2CO_3. The solution is put into a platinum dish of about 200 c.c. capacity, and connected with a single Bunsen cell, the positive or carbon pole being attached to a strip of platinum foil which dips in the liquid, and the wire from the other pole resting against the outside of the dish. A little Na_2CO_3 is added towards the end of the operation. To determine whether the precipitation is complete, the dish is tipped a little to see if Cu is deposited on the freshly-exposed surface of the platinum. It is usually safer, however, after weighing, to dissolve out with HNO_3 and put the solution in the dish again. Before weighing, wash quickly with water, then with alcohol, dry quickly, and weigh as soon as cool.

The work was done by Mr. E. H. S. Bailey, assistant in charge of the chemical laboratory, Lehigh University.

A. Cochrane.

The finely-pulverized ore was treated in a covered porcelain basin with strong nitric acid, under addition of a few cubic centimeters concentrated sulphuric acid. Heat was applied long enough to drive off the nitric acid; if sulphur had then separated, as always was the case here, the heat was increased in order to burn away all the sulphur present, more nitric acid was added, and the heating repeated. At last all acid vapors were driven off, the basin was allowed to cool, and the contents were boiled with pure water until nothing more dissolved. The residue was tested for copper, but none could be found. The solution was precipitated in a platinum dish with pure zinc, after addition of some dilute sulphuric acid; the excess of zinc was removed by adding more acid.

It might not be out of the way here to call attention to the fact, that the precipitated copper will very often cover the zinc in such a way that no evolution of gas takes place, even after addition of more acid, although there is, of course, an excess of zinc present. It is,

therefore, necessary to expose the surface of the zinc for the action of the acid by rubbing with a glass rod.

Although an excess of zinc can be removed mechanically, it seems best to effect that end by chemical means, as it will be found that copper has a strong tendency to adhere to the surface of the zinc. Indeed, a relatively quite strong acid is required to remove the black coating constituting the copper from the zinc.

The precipitation of the copper being complete, the metal was washed in the usual way with hot water as speedily as possible, until the washings gave no precipitate with $BaCl_2$, and then with alcohol. Having been dried on the water-bath and allowed to cool in the exsiccator, the copper was weighed without loss of time.

Some small amount of copper was always carried over with the washings. What could not be returned was dissolved in nitric acid, precipitated with potassic hydrate, and determined as oxide of copper.

In the following figures this amount of CuO—only a few milligrams every time—has been calculated as metallic copper and added to the other copper.

The work was done by Mr. Johan Enequist, chemist to Messrs. A. Cochrane & Co.

Dr. T. Egleston.

1st. 1 gram, precipitated electrolytically from H_2SO_4 solution, came down black. This was ignited, dissolved in HNO_3, and made alkaline with NH_4HO. The copper was precipitated with H_2S, and finally weighed as Cu_2S.

2d. 1 gram in H_2SO_4 solution, with 1 c.c. HNO_3, diluted to 100 c.c., precipitated electrolytically, came down black, and yielded 47.44 per cent. This was ignited, redissolved in HNO_3, and reprecipitated electrolytically in HNO_3 solution.

3d. 1 gram was dissolved in aqua regia, boiled with excess of HNO_3 till all HCl was destroyed, and precipitated electrolytically in HNO_3 solution.

4th. 11.3765 grams were dissolved as in No. 3, the residue was ignited, treated again with acid, and finally fused with $NaHSO_4$. The solutions obtained were diluted to 568.825 c.c. and 100 c.c. (= 2 grams) of this solution were taken.

The work was done by Mr. J. B. Mackintosh, Dr. Egleston's assistant.

Dr. F. A. Genth.

One gram of the finely-powdered ore is placed in a small beaker and enough of pure H_2SO_4 is added to convert all the metals into

sulphates and to drive off all the HNO_3 which is used for dissolving. The nearly dry mass, after having given off copious fumes of SO_3, is allowed to cool, and dissolved in a small quantity of water. When all excepting quartz, etc., is in solution, the trace of Ag which may be present is precipitated by a drop of HCl. When the liquid is clear, the insoluble silicates, $PbSO_4$, AgCl, and the greater part of antimoniate of antimony are separated by filtration from the Cu, As, etc. The clear liquid is next precipitated by H_2S, which throws down the CuS, and traces of Sb_2S_3 and As_2S_3—(the greater part of the As remains in solution, as the As_2O_5, for only a small amount is reduced to As_2O_3 in such a short time and precipitated by the H_2S). The CuS is washed, then treated with K_2S to dissolve the Sb_2S_3 and As_2S, which may have come down, and, after washing, boiled with strong HCl to dissolve any ZnS which may have been precipitated with the CuS, then diluted with boiling water, and a sufficient quantity of H_2S is added to precipitate any traces of Cu which may have gone into solution. The CuS is washed, dried, carefully roasted, then dissolved with 2 or 3 drops of H_2SO_4, H_2O, and HNO_3. After everything is in solution the latter is evaporated to dryness, carefully heated, and finally ignited to drive off every trace of H_2SO_4, and from the resulting CuO the amount of Cu is calculated.

This method gives, if care is taken that nothing is lost in the solution of the ore and the evaporation, etc., and if all the H_2SO_4 has been driven out, more accurate results than any other with which I am acquainted.

The resulting CuO is always dissolved in dilute H_2SO_4 and tested for its purity.

William Glenn.

For rich ores use 1 gram for assay; for poor ores, 2 grams; for slags, 3 grams. Mix and quarter the prepared sample until enough only is left for two assays. Weigh these into two 6-ounce beakers, cover both and set aside one for a duplicate determination. The solution mixture is 2.5 c.c. H_2SO_4 mixed with 9 c.c. HNO_3 for each gram of assay. Pour the mixture at once upon the assay and cover the beakers with a watch-glass. When action ceases, put the beaker on a water-bath and keep at about 100° until the solution is complete. Raise the watch-glass slightly, set the beaker on a sand-bath, and evaporate slowly until the mass would be pasty if stirred. Let cool and add 30 c.c. water and boil for half an hour. Filter into a 6-ounce beaker and deposit copper by electrolysis upon a cylinder of platinum foil suspended in the solution, using two Callaud

cells of 1 gallon capacity each. When the Cu is all deposited (known by testing with H_2S solution), wash the platinum cylinder three times in water and then in alcohol. Drain the alcohol quite completely from the copper, ignite the remainder, cool, and weigh. Examine all residues for Cu. The method leaves generally from 0.2 milligram to 0.4 milligram of copper in the solution.

For electrolysis use two Callaud cells for one assay and one additional cell for each additional assay. For example, three assays require four cells, six assays seven cells, and so on.

Proper management of battery is the only part of process requiring any skill.

W. M. Habirshaw.

Process: Solution by $HCl + HNO_3$.
Separation of the Pb as $PbSO_4$.
Precipitation of the Cu *twice* with H_2S.
Estimation, I. Precipitated in H_2SO_4 solution with $Na_2S_2H_2O_4$, ignited with excess of S in H gas, cooled in H gas, and weighed as Cu_2S.
II. Precipitated in platinum dish from HNO_3 solution as metallic Cu by galvanic current.

I do not think the mechanical condition of the first sample even enough to insure correct checking. I had to spend considerable time making it even throughout, and to avoid any error in this line took a weighing of 20 grams for the various methods.

Working on 2 grams from this large weighing, I found, I., 43.90 per cent. and 43.92 per cent. by precipitation as CuS. To-morrow I shall weigh duplicates from the battery method. The figures above I presume have been correctly calculated, but they have not been examined.*

R. R. Hedley.

Weigh 2 to 5 grams of ore, dissolve in 15 to 20 c.c. of aqua regia, evaporate and redissolve in 3 to 5 c.c. aqua regia, evaporate again to small bulk, and add about 10 c.c. H_2SO_4; boil to drive off all HNO_3,

* The results of the last two methods were handed me in New York on my way West about a month after receiving the first. Not having heard from Mr. Habirshaw I presumed he meant to stand by them. I take occasion in revising the paper to state this, and to say I understand now the first result was probably overlooked, and the last two were the ones Mr. Habirshaw intended for publication.

and for a few minutes after fumes of SO_3 appear. Then cool, dilute, boil, filter, and precipitate the copper on fine iron wire.

When all is precipitated (known by testing with H_2S solution) filter off the Cu precipitate, wash with water, and return all precipitate to same flask; redissolve in a little aqua regia, dilute, add NH_4HO, and titrate with a standardized solution of KCy.

F. F. Hunt.

No. 1. Take 1 gram of ore, dissolve in $HNO_3 + HCl + H_2SO_4$, heat till fumes of SO_3 are evolved, dissolve in water, filter, fuse residue with Na_2CO_3, dissolve in H_2SO_4, and add this filtrate to former one. Precipitate on platinum foil by battery with four gravity cells coupled two and two.

No. 2. Take 1 gram of finely-pulverized ore, dissolve as in No. 1, filter, and add fine iron wire to filtrate to precipitate the Cu; when completely precipitated (known by testing with H_2S), filter, dissolve the Cu in HNO_3, and precipitate by battery as before.

T. Kiddie.

The ore, after drying and pounding in the ordinary way, was evaporated to dryness with $HNO_3 + HCl$, and redissolved in HCl. The ferric salts were reduced to ferrous by Na_2SO_3, the excess of SO_2 was boiled off, and Cu was precipitated by H_2S, filtered, dried, ignited, redissolved in HNO_3, rendered ammoniacal, and titrated with KCy.

Mathey and Riotte.

Mohr's Method.—Dissolve in $H_2SO_4 + HNO_3$, make alkaline, and titrate with KCy.

Swedish Method.—Dissolve in $HNO_3 + HCl$, and add a few drops H_2SO_4; evaporate nearly to dryness, add water, filter, and wash; precipitate the Cu by iron wire, decant, wash, transfer to a weighed dish, wash with alcohol, dry, and weigh.

For particulars of above methods refer to Mitchell's assaying.

G. H. Nichols & Co.

The figures given represent the per cent. in the sample as received, not dried. As the amount of moisture is 0.21 per cent., the average result for dry sample would be 47.15 per cent. Cu.

The amount of the sample to be taken for analysis varies with its richness in Cu; for low grade ore 2 grams is a suitable quantity; for mattes below 50 per cent. 1 gram, while for black and pig copper 500 milligrams is the best quantity.

In the electrolysis of a copper solution the battery required has long been a very troublesome factor; the form which is now employed, however, seems to make but little trouble, and, unlike the Bunsen as ordinarily charged, to remain very constant. It consists of two Bunsen cells of 1 liter capacity. The charging fluid for the porous jar consists of equal quantities of a saturated solution of $K_2Cr_2O_4$ and concentrated HCl; for the outer jar pure water is used.

The process of solution would vary, of course, with the character of the ore; for sulphide ores it is most convenient to roast the sample in a shallow platinum dish at a low heat, and treat with about 15 to 20 cubic centimeters of HNO_3, preferably in a casserole. After heating till all nitrous fumes are expelled, and raising the acid to a boil, the cover is removed, rinsed, and the whole evaporated on the water-bath to a syrupy consistence, taken up with water, filtered, and made up to about 60 cubic centimeters. In the solution to be electrolyzed about 1 c.c. each of concentrated HNO_3 and H_2SO_4 is put, the latter to prevent any deposition of zinc which Classen declared possible in solution acidulated only with HNO_3, although with the battery power used it seems almost unnecessary, no deposition of zinc having been noticed when the H_2SO_4 was omitted.

The residue from treatment with HNO_3 is saved, but in case of pyrites, if not roasted at too intense a heat, it is free from copper.

For ores insoluble by such treatment, it may be necessary to use a mixture of H_2SO_4, HCl, and HNO_3, but in all cases no chlorides must be present in the solution when precipitation takes place.

For precipitating, the solution is put in a narrow beaker of about 75 c.c. capacity, the battery is charged by filling the inner jar half full of its acid mixture, while the outer jar is filled about one-third with water and the connection made.

The deposition apparatus is essentially that of Luckow, as is the method, the details being such as would readily suggest themselves to a person doing much copper work. Instead of a spiral wire, an inner cylinder is used, as tending perhaps to distribute the current more uniformly. The precipitation is allowed to continue eight to nine hours, the cylinder being taken out by lowering the beaker, at the same time rinsing the outer cylinder with the wash bottle. The copper-plated foil is now washed, dipped into alcohol, dried, and weighed.

If too strong a current is used it tends to blacken the copper; if now water is added to the inner jar the cause of the trouble is removed, while the blackened copper can readily be cleaned by raising and lowering the beaker containing the solution, thus alternately

exposing the foil to the air and to the fluid, and causing a resolution of the film last deposited.

The residue from the HNO_3 solution is now dissolved in HNO_3 + HCl, the solution from which the Cu has been precipitated is added to it, and the Fe is precipitated with a large excess of NH_4HO, the filtrate is concentrated to small bulk, and the small amount of copper is estimated colorimetrically by a Cu solution of 1 c.c. = 1 mg. Cu. This amount should be small, and not exceed 0.7–0.8 mg., and the color, when observed in a bulk of about 15 c.c., is easily sensible to $\frac{1}{10}$ mg.

Reference can be made for the behavior of other metals under the battery to Luckow's paper in Crookes's *Select Methods* and Watts's *Dictionary*. As there stated, As and Sb are not precipitated until all the Cu is deposited; in fact, with the battery power described above I have succeeded in depositing Cu free from As, when it was associated in solution with 20 per cent. of its weight of As. Where, however, the Cu is deposited bright and kept clean until the end, no fear need be entertained of its contamination from As or Sb, the roasting and treatment with HNO_3 removing these elements in large part. Bi and Ag are the two elements which must be most carefully looked after and removed if present.

The results with the electrolytic method, when proper care is taken, are susceptible of the utmost accuracy, and the method, while seemingly perhaps intricate, takes little actual time of the operator.

This work was done by Lucius Pitkin, analyst to G. H. Nichols & Co.

Pope, Cole & Co.

No description given in detail.

S. P. Sharples.

Take 2 grams and dissolve in $HNO_3 + H_2SO_4$, evaporate nearly to dryness, dissolve in water, filter, and precipitate Cu in platinum dish by the battery.

R. H. Richards.

Two grams of the ore were treated directly with concentrated HNO_3, which was used in sufficient quantity nearly, if not quite, to oxidize all the S in the ore; after standing on the steam-table for about an hour the solution was filtered, NH_4HO was added until the solution was only slightly acid, and H_2S was passed through the solution heated to boiling; after filtering, the sulphides were heated with S, and gently ignited (the crucible becoming only slightly red at the

utmost) for about thirty to forty-five minutes; the precipitate was then dissolved in a small amount of HNO_3, and the Cu was determined by the battery in the usual way.*

The work was done by John Duff, Jr., Assistant in charge of Mining Laboratory, Massachusetts Institute of Technology, Boston.

Stillwell & Gladding.

1. The ore is ground in an agate mortar to an impalpable powder and dried at 100° C.

2. One gram of the ore in the case of rich ores, or 2 grams in the case of poor ores, was roasted, thus expelling all the As and part of the Sb that may be present.

3. The roasted ore is next placed in a platinum dish, this covered with a watch-glass, 15 c.c. concentrated HNO_3 added, and the dish gently heated till the violent action has ceased. The cover is then removed, the dish placed on a water-bath, and the evaporation carried nearly to dryness, or till the contents are a thick paste. The $Cu(NO_3)_2$ is then taken up with hot water and filtered into a large platinum dish (250 c.c. capacity).

4. The copper is then precipitated on the dish by galvanic action, using two small cells.

5. After completion of the deposition of the copper, the dish is rinsed with hot water and then with alcohol, gently warmed, to evaporate the latter, and after cooling in the air is weighed.

6. Any trace of Cu undissolved by the HNO_3 is redissolved by aqua regia. The extra amount thus obtained, and any trace not completely deposited by the galvanic action, is estimated colorimetrically.

Description of Methods of Analysis Employed by the Different Chemists on the Sample of Copper Borings.

Dr. T. Egleston.

5.0095 grams were dissolved in HNO_3, the solution diluted to 500.95 c.c. and 100 c.c. (= 1 gram) taken and precipitated by battery as in the case of the ore. Done in duplicate.

The work was done by Mr. J. B. Mackintosh, Dr. Egleston's assistant.

William Glenn.

Same method as for the ore previously described.

* Professor Richards has since informed me that titanium is deposited with copper by electrolysis in nitric acid solution.—W. E. C. E.

Thomas Kiddie.

The method of analysis used in the estimation of the copper in the sample of borings was as follows: The whole of the copper was carefully mixed together in order to get an exact proportion of roughs and fines, and quartered down until each quarter weighed about 10 grams; two of these were weighed off,—the fines being swept in with a camel's-hair brush,—dissolved in HNO_3, cooled, and made up to 1 liter. Duplicate portions of 50 c.c. each were withdrawn, diluted with water, and the Cu was precipitated with H_2S, collected on a filter, washed with H_2S water, dissolved in HNO_3 (using a measured quantity of this and ammonia), rendered ammoniacal, and titrated with cyanide of potassium.

After the contents of the bottle were carefully mixed and quartered, I took two quarters for analysis and weighed them, then weighed off the same quantities of electrotype Cu dissolved in HNO_3, cooled, and made each up to 1 liter.

A. Took 100 c.c. of standard Cu solution and added 10 c.c. of NH_4HO.

B. Took 100 c.c. of solution of sample and added 10 c.c. of NH_4HO. Titrated both with KCy until the blue color began to disappear, filtered, and finished the titration with KCy, using color tubes to determine the end of the reaction.

G. H. Nichols & Co.

The same method as was described for the ore.

S. P. Sharples.

The same method as was described for the ore. The sample was mixed and quartered down to about 20 grams, the whole of it dissolved, and an aliquot part taken.

The two results are from different weighings.

On pig copper it is our custom to take the whole sample, and, by quartering it, to obtain a sample for analysis that will approximate 20 grams. This is then dissolved and made up to a liter, and 100 c.c. taken for the precipitation.

We find, even on material containing 4 or 5 per cent. of sand, that we can obtain duplicate analyses that will agree within two or three-tenths of one per cent., while with the same material, by merely shaking out of the bottle enough for an analysis, say 2 grams, our results may vary over 2 per cent. on the same sample.

THE ANTHRACITE COAL BEDS OF PENNSYLVANIA.

BY CHAS. A. ASHBURNER, PHILADELPHIA.

INTRODUCTION.

AT the Philadelphia meeting of the Institute, held in February, 1881, I had the honor of reading a paper on "A New Method of Mapping the Anthracite Coal Fields of Pennsylvania."* At that time the State appropriation for the Second Geological Survey had just expired, and, as a new appropriation was not assured, no detailed plan had been adopted by Professor Lesley, State Geologist, for the practical examination of the mines, and the solution of the geological structure of special localities, or the representation in sections, vertical and columnar, of the general structure of the coal basins and coal beds. I had merely proposed a plan of mapping, as the material for the construction of maps was most available, and it was at that time uncertain what money the Survey would have to enable it to extend the surface and underground explorations, in order to make the examinations complete. After a continuation of the Survey was authorized until January, 1884, by the legislature, in May, 1881, the Anthracite Survey was regularly organized, and a plan adopted for a systematic and exhaustive geological and mine examination of the region. This plan provided for such work, other than that of mapping, as was necessary for a complete and practical geological and mining survey of a coal field. To do any geological work, of however general a character, it was absolutely necessary that the members of the Survey Corps should obtain unrestricted access to all the mining records of the operators, which have been made with great care and accuracy and at an enormous expense during the past thirty years and more. The unanimous and generous support of the individual and corporate coal operators, of the plan of carrying on the Survey, was promptly assured, on condition that the results should be of such a character as to render them of practical utility to the property-owners and those directly interested. It was hoped

* Transactions, vol. ix, p. 506.

that the entire field-work of the Survey might be completed before the expiration of the present appropriation; but, with the conditional assistance offered by those who possessed the records which must constitute the basis of the work, it became absolutely necessary to prosecute the examination with great care and thoroughness, and to publish the results in such a manner, as to satisfy the practical demands; and in consequence, the policy of the Survey was from necessity changed, as far as a limitation of time was placed upon the work. Field parties were organized in the three districts of Wyoming and Lackawanna, Lehigh, and Schuylkill. The corps, which it was possible to place in each locality, was small, on account of the limited means of the Survey, and, in consequence, the progress of the work has been necessarily slow.*

The charts of the Survey are to be published of uniform size (26 by 32 inches) and on the following scales:

1. Mine maps, showing the mine workings and the structure of the coal-beds by underground contour curves 50 feet vertically apart. Scale 800 feet = 1 inch.

2. Topographical maps of the surface of the coal basins in contour curves 10 and 20 feet vertically apart. Scale 1600 feet = 1 inch.

3. Vertical cross sections of the coal basins. Scale 400 feet = 1 inch.

4. Columnar sections of the coal measures, showing the relation of the coal-beds and the character of the rock intervals. Scale 40 feet = 1 inch.

5. Columnar sections of the individual coal-beds. Scale 10 feet = 1 inch.

These sheets will be supplemented by others of a miscellaneous character.

As the charts illustrating the individual districts shall be completed, they will be immediately published and issued, with a brief explanatory report of the special features which they represent. The general geological report of the region will not be published until the survey of the entire field is completed. This plan will very much lengthen the work, but will insure the practical value of the results.

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* Up to the present time the survey of the Panther Creek basin, between Mauch Chunk and Tamaqua, has been completed. The surveys of the following basins will be completed within a few weeks: Wilkes-Barre, between Shickshinny and Wilkes-Barre (Northern Coal Field), Black Creek, and Hazleton basins (Eastern Middle Coal Field), and that portion of the Mahanoy and Shenandoah basins (Western Middle Coal Field), lying between Delano and Ashland.

Identity of Coal Beds.

One of the most important questions to be examined and reported on by the Survey is the identification of the coal beds which are being worked in the mines of the same, or of different, basins. The difficulties in the way of a solution of this problem are very great, and in special localities are appreciated by those practically interested. The information which is in the possession of any one engineer in the region, however extensive his connections, is seldom such as to enable him to identify the beds over any very considerable area; certainly not for the entire coal field.

The idea is prevalent, that the identity and relation of the coal beds have been established beyond doubt, and that certain of the anthracite beds have been identified as the representatives of the bituminous beds in the western part of the State. To what extent this has been accomplished, as far as the anthracite beds are concerned, the facts presented here will show.*

Since the Geological Survey has been in progress, numerous demands have been made for columnar sections of the coal measures, in special localities, in order to determine the identity and relation of particular

* Prof. Rogers in his final report of the First Geological Survey published in 1858 attempted to systematize the conflicting names assigned to the coal beds. The information which the assistant geologists were able to obtain at that time was too meagre to permit of a rectification of all of the inconsistencies. In some localities, where it was believed that the same bed had been given different names, too little was certainly known of the structure to permit of a final solution. In introducing this subject Prof. Rogers says: "Much pains have been devoted, in the progress of the Geological Survey of the Anthracite region, to noting and recording the characteristic features of the individual coal seams, to tracing the variations of type which they undergo, to ascertaining their identity from section to section, and the double names which many of them possess. From the circumstances that, from the commencement of mining operations, in the southern basin especially, down to the present day, the chief collieries and explorations for coal have started in the valleys which intersect the basins, the identity of the beds, from valley to valley, remains even yet imperfectly known. In the absence of such knowledge of the equivalencies of the locally opened beds, it was natural, indeed inevitable, that the miners should assign either local names, or apply the known names of distant coals erroneously to their own favorite seams. A desire to apply to a newly found coal, or a newly organized mine, the name of some bed of established repute nearly in the same range with it, where a scrupulous tracing of their outcrops might have proved them dissimilar, has added not a little to the excessive confusion of nomenclature which now exists, to the serious detriment of the mining interests of the region."

"Not a few of the disastrous disappointments which attend mining enterprise in the Pottsville Basin may be attributed to the prevailing ignorance of the true range and identity of its coal beds, one main source of which, next to a want of clear tracing of the anticlinal and synclinal flexures, is the confusion in the naming of the coal beds."

coal beds. As the detailed information in possession of the Survey will not be available to the public, until it is systematized and results deduced and placed in form to be published, it has not yet been possible to meet these requests. The importance of this question to the property-owner and miner will be appreciated, when it is considered that, if it is not certainly known what coal bed is being mined, the number or character of the coal-beds above or below it can only be a matter of conjecture. The anthracite coal beds have all, long since, been named; and in many instances the same names have been indelibly affixed to beds of well-recognized characteristics over the entire region from Scranton to Tremont. The natural inference has been that any one of these well-known names designates always the same bed, wherever it may be used. In many cases this is a fact; in many others the supposed identification of the beds has been established upon insufficient grounds, and a similarity of name does not indicate an identity of beds.*

In the case of some of the large mining companies, whose operations are spread over a vast territory, this subject has received a careful study from their engineers and colliery superintendents, and the relationship of the beds has been established. Notable instances could be named, however, where a mistaken identity of the beds on properties immediately adjoining those of the larger companies have not only produced complications in mining, but have increased or depreciated property values. In general, these errors have come from a supposed parallelism of the coal beds, or from placing too much importance upon a similarity of coal as indicative of an identity of bed. The non-parallelism of the anthracite beds is now proved beyond a question; in fact, I am not disposed to regard with favor the certain identification of any of the Carboniferous strata, over the entire coal field, other than the Mammoth bed and the base of the Pottsville Conglomerate, No. XII (Carboniferous Conglomerate, Millstone Grit, or Seral of Rogers). Even in these two cases I could cite instances which have recently caused the Assistant Geologists of the Survey and myself much perplexity. These difficulties have arisen in parts of the coal basins which have been most thoroughly and longest worked.

The following sections which have been measured in prominent localities throughout the region, show the best known local names, and the relation of the coal beds, together with their average thick-

* A short time ago I was informed, on good authority, that a bed being worked in a certain mine had been named after another bed elsewhere, because the latter produced a grade of coal which stood high in the market.

ness, and the thickness of the Carboniferous formation,* in the several basins, which is known at present to contain workable beds. I have selected a typical section in each basin, and have placed it on the accompanying chart, so that the bottom of the Mammoth bed so called in each case is on a horizontal line across the sheet. I believe it is quite impossible at present to identify the individual beds from section to section.

SECTION No. 1.

POTTSVILLE BASIN. AUTHORITY: PHILADELPHIA AND READING COAL AND IRON COMPANY.

Belmont Estate, East of Pottsville.

	Rock.	Coal Beds.
1. Lewis coal bed,†		8 feet.
2. Interval,‡	210	"
3. Spohn coal bed,		8 "
4. Interval,	210	"
5. Palmer coal bed,		3 "
6. Interval,	263	"
7. Charlie Pott coal bed,		3 "
8. Interval,	78	"
9. Clarkson coal bed,		7 "
10. Interval,	83	"

* It is difficult to state any thickness for a coal bed, or for the rock intervals between the beds, which shall be an average for any area, as both are known to change within very short distances. A notable instance, as regards the coal, is found in the No. 9 Colliery of the Lehigh Coal and Navigation Company, nine miles west of Mauch Chunk, in Carbon County, as is shown in the following table:

Distance from Tunnel No 9.	Thickness of Mammoth Coal Bed.	Thickness of Coal.
4129 feet east,	49	42.5
3926 " west,	73	66
4017 " "	114	106

On the property of the same company, the interval between the top of the Mammoth bed and the bottom of the Red Ash, F, or Primrose bed, varies from 164 feet at Tunnel No. 1, to 288 feet at Tunnel No. 9, which is six miles west of Tunnel No. 1.

† The rock intervals are generally filled with dark-gray slate, generally very argillaceous, sometimes ferruginous, but, as far as I know, never calcareous; with sandstones of varying degrees of coarseness and hardness, generally massive and compact, sometimes shaly; and with conglomerates. These latter are mostly found below the Mammoth bed. The difference in the hardness of the rocks above and below this bed is well illustrated by the fact that the Pennsylvania Diamond Drill Company, which has put down a great many proving-holes in the region, charges $5 a foot for drilling above this bed, and $6 for drilling below it.

‡ A coal-bed sometimes consists of several benches of good coal alternating with bony coal, too poor to mine or to burn, and slate. The thicknesses assigned to the coal-beds in the accompanying sections, in consequence, represent much more than the actual thickness of coal which can be mined for fuel. The amount of good coal in the different beds varies very much; sometimes the proportion is so small as compared with the bony coal and slate that, although the bed may be of ample thickness, it cannot be economically worked.

	Rock.	Coal Beds.
11. Selkirk coal bed, ...		7 "
12. Interval, ...	120	"
13. Leader of coal, ...		3 feet.
14. Interval, ...	45	"
In Vicinity of Pottsville Shafts.		
15. Peach Mountain coal bed, ...		5 "
16. Interval, ...	60	"
17. Coal bed, ...		3 "
18. Interval, ...	58	"
19. Little Tracy coal bed, ...		6 "
20. Interval, ...	198	"
21. Coal bed, ...		2 "
22. Interval, ...	40	"
23. Little Diamond coal bed, ...		3 "
24. Interval, ...	122	"
25. Diamond coal bed, ...		6 "
26. Interval, ...	158	"
27. Little Orchard coal bed, ...		3 "
28. Interval, ...	25	"
29. Orchard coal bed, ...		4 "
30. Interval, ...	190	"
31. Primrose coal bed, ...		8 "
32. Interval, ...	91	"
33. Holmes coal bed, ...		4 "
34. Interval, ...	70	"
35. Leader of coal, ...		4 "
36. Interval, ...	140	"
37. Mammoth (Top split) coal bed, ...		7 "
38. Interval, ...	15	"
39. Mammoth (Bottom split) coal bed, ...		25 "
40. Interval, ...	60	"
41. Skidmore coal bed, ...		8 "
42. Interval, ...	72	"
43. Seven-foot coal bed, ...		3 "
44. Interval, ...	80	"
45. Leader of coal, ...		— "
46. Interval, ...	25	"
47. Leader of coal, ...		2 "
48. Interval, ...	25	"
49. Buck Mountain coal bed, ...		8 "
Eckert Colliery, Tremont.		
50. Interval, ...	554	"
51. Coal bed, ...		2 "
52. Interval, ...	50	"
53. Coal bed, ...		2 "
54. Interval, ...	55	"
55. Lykens Valley coal bed, ...		10 "
	3097	154 "
Total length of section, ...		3251 "

The upper part of this section, above the Peach Mountain bed, is located about 14 miles (air-line) east of Tremont, where the lower part of the section below the Buck Mountain bed has been measured; while the section between these two beds, measured in the vicinity of the Pottsville shafts, is between Tremont and the Belmont estate, in fact, but a short distance west of the latter locality. The entire section, as it has been compiled and reported to me by Mr. Bard Wells, Assistant Geologist, may be said to represent fairly the succession and thickness of the strata of the Southern Field, but does not necessarily represent what would be absolutely found in any one place by commencing to drill in the Lewis bed and piercing the entire series down to the Lykens Valley coal bed. The names given to the beds in this section are not universally accepted by the local geologists and engineers. There are important questions of identity involved which cannot be settled until the geology has been carefully studied throughout the Pottsville basin.

SECTION No. 2.

PANTHER CREEK BASIN.—AUTHORITY: LEHIGH COAL AND NAVIGATION COMPANY AND GEOLOGICAL SURVEY.

	Rock.	Coal Beds.
Upper Red-Ash Group.		feet.
1. Interval,	216	
2. Third Upper Red-Ash coal bed,		1 "
3. Interval,	63	"
4. Second Upper Red-Ash coal bed,		3 "
5. Interval,	106	"
6. First Upper Red-Ash coal bed,		4 "
7. Interval, *Lower Red-Ash Group,* 7. Interval,	158	"
8. Coal bed, } Second Twin beds,		2 "
9. Interval, } Second Twin beds,	13	"
10. Coal bed, } Second Twin beds,		2 "
11. Interval,	128	"
12. Coal bed, } First Twin beds,		2 "
13. Interval, } First Twin beds,	13	"
14. Coal bed, } First Twin beds,		2 "
15. Interval,	38	"
16. Jock coal bed,		7 "
17. Interval,	92	"
18. Washington coal bed,		3 "
19. Interval,	84	"
20. G coal bed,		6 "
21. Interval,	46	"
22. Bony coal bed,		4 "
23. Interval,	55	"
24. F coal bed,		10 "

White-Ash Group,

		Rock.	Coal Beds.
25. Interval,		211	feet.
26. E coal bed,	Mammoth coal bed,		24 "
27. Interval,		45	"
28. Cross-cut coal bed,			5 "
29. Interval,		48	"
30. D coal bed,			12 "
31. Interval,		122	"
32. C coal bed,			8 "
33. Interval,		175	"
34. Coal bed,			—
35. Interval,		55	"
36. B coal bed,			9 "
37. Interval,		115	"
38. A coal bed,			16 "
Lykens Valley Group.			
39. Interval,		240	"
40. Upper Lykens Valley coal bed,			6 "
41. Interval,		145	"
42. Lower Lykens Valley coal bed,			? "
		2168	126 "
Total length of section,			2294 "

This section is unlike the section given for the Pottsville basin, inasmuch as it represents the succession of strata in one locality. The measurements were made in and about the mines north of Tamaqua, on the east side of the Little Schuylkill River, and through the Locust Mountain Gap, where the entire series of strata represented in the section dip away from the Locust Mountain southwest toward the town of Tamaqua, to a point on the river midway between Elm and Vine streets. Here a reverse dip on the south side of the Panther Creek basin is encountered, the centre of the basin or synclinal being located at this point. In other words, if a diamond drill-hole should be started at the point indicated and drilled in a direction (N. 18° 30′ W.) perpendicular to the strike of the rocks and at the same time perpendicular to the dip or pitch of the beds, or at an angle of 30 degrees with the horizon, the section here given should show the coal beds and their distances apart, as would be found in the drill-hole.*

* The coal beds at Tamaqua were originally named from A to T, A being the first bed which was known at that time in the Locust Mountain Gap going south, and T being the most southern bed which was known to exist in the Sharp Mountain Gap. Although it was a well-recognized fact by those who had some understanding of the geology of the Tamaqua section that the same bed at different outcrops and in different basins was assigned different letters, yet the idea that there were actually 20 individual coal beds, one above the other, at Tamaqua, was quite prevalent. My attention was only recently called to this fact by an engineer in the

SECTION No. 3.

SHAMOKIN BASIN.—AUTHORITY: PHILADELPHIA AND READING COAL AND IRON COMPANY.

Treverton Estate.

	Rock.	Coal Beds.
1. No. 16 coal bed,		5 feet.
2. Interval,	63 "	
3. No. 15 coal bed,		5 "
4. Interval,	79 "	
5. No. 14 coal bed,		8 "
6. Interval,	30 "	
7. Leader of coal,		1 "
8. Interval,	55 "	
9. No. 13 coal bed,		6 "
10. Interval,	70 "	
11. No. 12 (Orchard) coal bed,		4 "
12. Interval,	163 "	
13. No. 11 (Primrose) coal bed,		7 "
14. Interval,	100 "	
15. No. 10 (Holmes) coal bed,		3 "
16. Interval,	85 "	
17. No. 9 (Mammoth [Top split]) coal bed,		10 "
18. Interval,	47 "	
19. No. 8 (Mammoth [Bottom split]) coal bed,		10 "
20. Interval,	112 "	
21. No. 7 (Skidmore) coal bed,		3 "
22. Interval,	72 "	
23. No. 6 (Seven-foot) coal bed,		7 "
24. Interval,	129 "	
25. No. 5 (Buck Mountain) coal bed,		22 "
26. Interval,	130 "	
27. Leader of coal,		5 "
28. Interval,	153 "	
29. No. 1 (Upper Lykens Valley) coal bed,		11 "
30. Interval,	120 "	
31. No. 0 (Lower Lykens Valley) coal bed,		10 "
	1408	117 "
Total length of section,		1525 "

This section has been measured by the engineers of the Philadelphia and Reading Coal and Iron Company on the Treverton estate, which is at the extreme western limit of the Western Middle Coal Field. There are difficulties and changes in the stratigraphy of the Shamokin basin which render it almost impossible to select any one section as typical of the entire district. Some of the sections on the property of the

region, who thought that even now there were many persons in the coal region who believed in the existence of all of these separate beds.

Mineral Railroad and Mining Company, near Shamokin, differ widely in detail from this of the Treverton estate. This is the only section given in the series where the beds have been numbered.

SECTION No. 4.

SHENANDOAH AND MAHANOY BASINS.—AUTHORITY: PHILADELPHIA AND READING COAL AND IRON COMPANY.

Vicinity of Ellangowan Colliery.

	Rock.	Coal Beds.
1. Big Tracy coal bed,		4 feet.
2 Interval,	55	"
3. Diamond coal bed,		7 "
4. Interval,	118	"
5. Little Orchard coal bed,		3 "
6. Interval,	24	"
7. Orchard coal bed,		11 "
8. Interval,	152	"
9. Primrose coal bed,		8 "
10. Interval,	100	"
11. Holmes coal bed,		13 "
12. Interval,	6	"
13. Coal bed,		4 "
14. Interval,	131	"
15. Mammoth (Top split) coal bed,		12 "
16. Interval,	39	"
17. Mammoth (Middle split) coal bed,		8 "
18. Interval,	23	"
19. Mammoth (Bottom split) coal bed,		15 "
20. Interval,	21	"
21. Skidmore coal bed,		4 "
22. Interval,	24	"
23. Seven-foot coal bed,		7 "
24. Interval,	71	"
25. Buck Mountain coal bed,		12 "
	764	108 "
Total length of section,		872 "

This section was compiled to accompany the map* of the mines between Mahanoy City and Shenandoah, which is being published by the Geological Survey, and is supposed to be a typical section of the coal measures of that region. There are a great many changes between these two points, both in the thickness of the coal beds and the rocks which separate them. The section would represent more particularly the stratigraphy in the vicinity of the Ellangowan col-

* Volume No. 1, "Western Middle Coal Field," Mine Sheet No. 11.

liery. Although the Big Tracy bed is placed at the top of the section, there is at least 125 feet of strata on top of it.

SECTION No. 5.

HAZLETON BASIN.—AUTHORITY: THOMAS S. MCNAIR.

Hazleton Colliery.

	Rock.	Coal Beds.
		feet.
1. Interval,	45	
2. Twin coal bed,		12 "
3. Interval,	154	"
4. Coal bed,		1 "
5. Interval,	3	"
6. Coal bed,		9 "
7. Interval,	41	"
8. Coal bed,		4 "
9. Interval,	6	"
10. Coal bed,		7 "
11. Interval,	128	"
12. Mammoth coal bed,		33 "
13. Interval,	45	"
14. Wharton coal bed,		9 "
15. Interval,	26	"
16. Gamma coal bed,		2 "
17. Interval,	61	"
18. Buck Mountain coal bed,		8 "
19. Interval,	16	"
	525	85 "
Total length of section,		610 "

This section has been constructed from data obtained in diamond-drill bore-holes, shafts, and mine-workings near the middle of the Hazleton basin. It is probably as typical of the entire basin as any that could be constructed. The beds overlying the Mammoth apparently run out to a feather edge in the western part of the basin; at least, the developments in the local basin seem to indicate that this is the case. The main basin has not been sufficiently developed in this part of the section to form a general opinion. According to Mr. A. P. Berlin, Assistant Geologist, the beds underlying the Mammoth become more numerous toward the west, and the principal ones (Wharton and Buck Mountain) are more than 89 feet apart, which is the distance indicated in the above section. The Gamma bed, in the western end of the basin, attains a thickness of 4 feet, including 1 foot 6 inches of slate, etc. The Parlor bed, under the Mammoth bed, is not located in this section.

SECTION No. 6.*

BLACK CREEK BASIN.—AUTHORITY: COXE BROTHERS & Co.

Gowen Bore Hole, No. 1.

	Rock.	Coal Beds.
1 (Mammoth coal bed,†		27 feet.)
2. Interval (top of drill hole),	50	"
3. Coal bed,		9 "
4. Interval,	65	"
5. Wharton (Top split) coal bed,		10 "
6. Interval,	15	"
7. Wharton (Bottom split) coal bed,		6 "
8. Interval,	94	"
9. Gamma (Top split) coal bed,		2 "
10. Interval,	40	"
11. Gamma (Bottom split) coal bed,		4 "
12. Interval,	29	"
13. Buck Mountain coal bed,		12 "
14. Interval,	46	"
15. Coal bed,		3 "
16. Interval,	47	"
17. Coal bed,		1 "
	386	74 "
Total length of section,		460 "

This section is constructed from the record of a bore-hole drilled by Coxe Brothers & Co. at Gowen, in the West Cross Creek basin, which is one of the Black Creek basins. The geology is very much confused at this point, so that the names given to the beds in the section, and which were assigned to them at the time the hole was drilled, may not be correct. This hole was bored in 1876; but a few months ago I was told that the engineers of the company knew less about the structure of this basin and the identity of the beds than when the diamond-drill core was first studied in 1876, and names given to the different beds. This conclusion, arrived at after a close and careful study of the facts which have been developed in this

* This section was copied from a constructed section of the bore-hole in November, 1880. The total thicknesses of coal beds and rock intervals differ *slightly* from those given in a more detailed written record of the bore-hole recently received. The latter will be published in full in the Geological Report of the Eastern Middle Coal Field.

† The top of the Gowen bore-hole is located below the Mammoth bed, so that this bed is not pierced by the drill here. The bed has, however, been placed above the record of the Gowen hole, as the section without it would not be a representative one of the basin. The thickness of 27 feet is taken from the Ebervale section, given below. The section of Conglomerate strata pierced in the lower part of the hole is not given.

basin during six years, is not an exceptional one. Although it is the popular opinion that the geology of the anthracite coal fields has long since been settled, I know of no fresher field for the mining geologist to work in than this, and none where his work, if carefully and intelligently done, would be of more practical and economical value.

The following section represents the strata in the Black Creek basin, midway between Ebervale and Jeddo, on what is known as the Jeddo property, 800 feet east of the Ebervale property.*

	Rock.	Coal Beds.
1. Interval,	198	feet.
2. Mammoth coal bed,		27 "
3. Interval,	21	"
4. Parlor coal bed,		5 "
5. Interval,	45	"
6. Wharton coal bed,		2 "
7. Interval,	46	"
8. Buck Mountain coal bed,		1 "
9. Interval,	39	"
10. A coal bed,		1 "
11. Interval,	20	"
	369	36 "
Total length of section,		405 "

The Mammoth bed in this section is given as 27 feet thick; this is probably an average, although it is as difficult to assign an average thickness to this bed in the Black Creek basin as anywhere in the region. Calvin Pardee & Co., near Hollywood and Milnesville, are at present stripping this bed in places where it has a thickness between 60 and 90 feet over a large area. In one place, directly in the centre of the basin, it measures as much as 102 feet thick. Next to the bed in Colliery No. 9 of the Lehigh Coal and Navigation Company, where it measures 114 feet, as already noted, this is the greatest thickness of coal that I know of in the anthracite coal fields. These thick beds are not economically worked. In my judgment, a property containing ten beds of anthracite, each 10 feet thick, is very much more valuable to the operator than one containing a bed 100 feet thick.

* These two properties are both owned by the Union Improvement Company; that portion known as the Ebervale property is leased and operated by the Ebervale Coal Company; the eastern section of the property, which is generally known by the name of Jeddo, is leased and operated by G. B. Markle & Co.

SECTION No. 7.

NANTICOKE BASIN.—AUTHORITY: SUSQUEHANNA COAL COMPANY.

Susquehanna Shafts Nos. 1 and 2.

	Rock.	Coal Beds. feet.
1. Interval,	83	
2. Coal bed,		2 "
3. Interval,	23	"
4. Diamond, George, or I, coal bed,		4 "
5. Interval,	90	"
6. Coal bed,		2 "
7. Interval,	82	"
8. Orchard, Tunnel, or H, coal bed,		10 "
9. Interval,	72	"
10. Hillman, Slope, or G, coal bed,		8 "
11. Interval,	47	"
12. Coal bed,		3 "
13. Interval,	13	"
14. Lance, or Four-foot, coal bed,		5 "
15. Interval,	35	"
16. Cooper coal bed,		10 "
17. Interval,	37	"
18. Bennett, Forge, or E, coal bed,		7 "
19. Interval,	120	"
20. Twin coal bed,		20 "
21. Interval,	19	"
22. Coal bed,		2 "
23. Interval,	123	"
24. Ross, or C, coal bed,		5 "
25. Interval,	28	"
26. Three-foot coal bed,		3 "
27. Interval,	52	"
28. Coal bed,		3 "
29. Interval,	37	"
30. Coal bed,		2 "
31. Interval,	37	"
32. Buck Mountain, or B, coal bed,		10 "
33. Interval,	13	"
34. Red Ash coal bed,		6 "
	911	102* "
Total length of section,		1013 "

* In stating the thickness of strata, in general sections, it is customary to disregard the inches and give the thicknesses to the nearest foot. In sections of shafts such as these, where the measurements have been recorded to inches with the utmost care, it is difficult to state the thicknesses in feet in order to make the total summation correct. In these shafts there are minute coal seams under 6 inches, which would make the total thickness of *coal beds* about 104 instead of 102 feet. Some of the beds contain a great deal of bony coal and slate.

This section, like the others given in the Northern (Wyoming and Lackawanna) Coal Field, is of great local interest and value, and shows the exact stratification of the coal measures at Nanticoke, as the others do at Wilkes-Barre, Scranton, Carbondale, and in the vicinity of Forest City colliery. The difficulty of selecting a section in this field, typical of any considerable area, has been greater than in the more southern fields. The development and mining of coal in the Northern Field has been more independently conducted, and there has been less interchange of information between the mining engineers and operators than elsewhere. In addition to this, the mines are more scattered and, in the main, the basins are more shallow than in the Lehigh or Schuylkill regions. As a result, there are not as many different beds being mined in special areas. These facts have rendered it very difficult for the beds to be properly identified, and the work which is left here for the Geological Survey is probably greater and beset with more embarrassments than anywhere else, although in no region is this kind of information more desired or more necessary to the property-owners. A great many records of shafts and diamond-drill holes have been obtained by Mr. Frank A. Hill and his assistants in the Wilkes Barre office. Many of these are held confidentially until they shall be finally systematized and arranged for general publication, so that it is impossible at present to even suggest a final comparison of the beds given in the Northern Coal Field sections. On the accompanying chart the sections have been placed so that what is generally considered to be the representative of the Mammoth bed is placed horizontally opposite the Mammoth bed in the Lehigh and Schuylkill sections. The confusion of names is very great in this field; for instance, the Hillman bed is known also as the Slope, G and H. The next bed above this one is known locally as the Lance, Kidney, Bowkley, Mills, Orchard, and Tunnel bed. The bed above this one is locally known by the following names, Hutchinson, Seven-foot, Diamond, George. A study and comparison of these sections cannot fail to convince the most indifferent of the necessity of the thorough and exhaustive examination of this and of the other anthracite coal basins.

I have no special reference to make to any of the following sections, other than to remark, as I have done in speaking of the other sections, that the thickness of the beds are subject to many local changes, and in special localities may be more or less than given here.

SECTION No. 8.

WILKES-BARRE BASIN.—AUTHORITY: LEHIGH AND WILKES-BARRE COAL COMPANY, AND DELAWARE AND HUDSON CANAL COMPANY.

Conyngham Shaft.

	Rock.	Coal Beds.
1. Interval,	60	feet.
2. K coal bed,		11 "
3. Interval,	60	"
4. J, Seven-foot, or Abbott, coal bed,		5 "
5. Interval,	77	"
6. I, Kidney, or Bowkley, coal bed,		5 "
7. Interval,	52	"
8. H, or Hillman, coal bed,		16 "
9. Interval,	150	"
10. G coal bed,		3 "
11. Interval,	57	"
12. F coal bed,		3 "
13. Interval,	128	"
14. E, Baltimore, or Mammoth, coal bed,		16 "
Baltimore Bore Hole.		
15. Interval,	106	"
16. Coal bed,		2 "
17. Interval,	26	"
18. Coal bed,		1 "
19. Interval,	88	"
20. D (?) coal bed,		4 "
21. Interval,	7	"
22. Coal bed,		1 "
23. Interval,	21	"
24. C, or Ross, coal bed,		7 "
25. Interval,	28	"
26. B, or Red-Ash, coal bed,		17 "
27. Interval,	3	"
28. A coal bed,		3 "
	863	94 "
Total length of section,		957 "

SECTION No. 9.

LACKAWANNA BASIN.—AUTHORITY: DELAWARE, LACKAWANNA, AND WESTERN RAILROAD COMPANY.

Vicinity of Scranton.

	Rock.	Coal Beds.
1. Interval,	35	feet.
2. A coal bed,		10 "
3. Interval,	89	"
4. B coal bed,		2 "
5. Interval,	45	"
6. C coal bed,		6 "

	Rock.	Coal Beds.
7. Interval, ...	32	feet.
8. D coal bed, ...		7 "
9. Interval, ...	90	"
10. E, or Diamond, coal bed, ...		6 "
11. Interval, ...	39	"
12. F, or Rock, coal bed, ...		6 "
13. Interval, ...	117	"
14. G, or Big, coal bed, ...		10 "
15. Interval, ...	53	"
16. H, or New County, coal bed, ...		8 "
17. Interval, ...	40	"
18. J, or Clark, coal bed, ...		6 "
19. Interval, ...	52	"
20. K coal bed, ...		5 "
21. Interval, ...	41	"
22. L coal bed, ...		6 "
	633	72 "
Total length of section, ...		705 "

SECTION No. 10.

Carbondale Basin.—Authority: Hillside Coal and Iron Company.

Vicinity of Carbondale.

	Rock.	Coal Beds.
1. Interval, ...	21	feet.
2. Coal bed, ...		2 "
3. Interval, ...	25	"
4. Coal bed, ...		2 "
5. Interval, ...	24	"
6. Archibald, or Carbondale, coal bed, ...		7 "
7. Interval, ...	42	"
8. Coal bed, ...		1 "
9. Interval, ...	172	"
	284	12 "
Total length of section, ...		296 "

SECTION No. 11.

Carbondale Basin.—Authority: Hillside Coal and Iron Company.

Forest City Colliery.

	Rock.	Coal Beds
1. Interval, ...	46	feet.
2. Coal bed, ...		2 "
3. Interval, ...	12	"
4. Coal bed, ...		6 "
5. Interval, ...	33	"
6. Coal bed, ...		1 "
7. Interval, ...	57	"
8. Coal bed, ...		4 "

	Rock.	Coal Beds.
9. Interval, ...	33	feet.
10. Coal bed, ...		1 "
11. Interval, ...	81	"
12. Coal bed, ...		8 "
13. Interval, ...	41	"
	303	22 "
Total length of section, ...		325 "

Résumé.—No attempt has yet been made by the Geological Survey to systematize these sections. In fact, I believe it is quite impossible to do so. A careful study of the information contained in these sections cannot fail to show the inconsistencies in naming the beds and the difficulties, which at present seem almost insurmountable, in the way of either identifying the beds over the entire region, or of proposing any plan of naming which would not lead to errors.

The following may be noted as a few of the inconsistencies shown on the accompanying sheet of sections.

In Section No. 2 the F, or first bed above the Mammoth, is frequently called the Primrose bed, between Mauch Chunk and Tamaqua, while in the western part of the Southern Coal Field and in the Western Middle Coal Field, the second bed above the Mammoth is generally called the Primrose, the first bed above the Mammoth, which is worked in a number of localities in these basins, being known as the Holmes bed.

The B bed and Buck Mountain bed are generally considered to be the same. The name Buck Mountain has been generally assigned to the lowest workable coal bed in the region, exclusive of the Lykens Valley beds. Along the Locust Mountain, north of Tamaqua, however, there is a coal bed (called A), 16 feet thick,* 115 feet under the bed which has been named B or Buck Mountain. This A bed has been extensively worked here, and has produced good coal.

At Tamaqua the bottom bench or split of the Mammoth bed is named D. At Nanticoke (Section No. 7) the Twin bed, which is 120 feet under the Bennett, Forge, or E, bed (which at this point is considered to be the bottom split of the Mammoth), is sometimes named D. At Wilkes Barre (Section No. 8) the D bed is the third under the Baltimore or Mammoth, and 223 feet below it. In the Lackawanna basin (Section No. 9) the D bed is the third bed above the Big bed, which is supposed to be the Mammoth, with an interval between the two of 258 feet. In the former cases the beds are lettered from the bottom up; in the latter, from the top down. In this instance the

* The average thickness of this bed here is probably about 6 feet.

inconsistency in naming may be readily understood, and need not occasion errors in the comparison of sections, if it is known for a certainty in a written section whether the highest or lowest geological stratum is recorded first. As there is no general rule in recording a written section, great difficulty is sometimes experienced in ascertaining which is top and which is bottom.

The total thickness of coal which can be economically mined in each basin, with the present system of mining, may not be as great as the total coal in feet given for each section, which, in some places, is made to include beds as low as one foot in thickness; for at present it is not generally considered profitable to mine an anthracite coal bed which is under 4 or 5 feet thick. The variability of the thickness of the beds is such, however, that in many cases the total coal which can be mined may be greater than that given,* while in special instances the thickness assigned to the workable beds may be excessive. As a general rule, the total coal given can be considered to represent the total workable coal in localities where the entire section is found to exist.

TOTAL AMOUNT OF COAL IN THE REGION.

A great many estimates have been made of the total contents of the anthracite coal beds of Pennsylvania. These estimates, however, have been based upon data of a very general nature, and their authors never claimed for them great accuracy. The areas of the fields have never been carefully measured, so that it would, of course, be impossible to determine with much exactness the total contents. These estimates can be better made after the completion of the Geological Survey.

The following table gives what I consider to be the most accurate statement of the areas that has ever been made.† With the exception of the Panther Creek basin, the area of which has already been determined by the Geological Survey, the table is compiled mostly from the estimates of Mr. P. W. Sheafer.

	Square miles.
Northern Coal Field,	198
Eastern Middle Coal Field,	37
Western " " "	91
Southern " " (exclusive of Panther Creek Basin),	130
Panther Creek Basin,	12.5
Total area,	468.5

* The Mammoth bed in the Black Creek basin (Section No. 6) is given as 27 feet thick. This bed, as has been noted, is worked by Calvin Pardee & Co., in the Hollywood quarries, where it sometimes measures as much as 102 feet. The coal is obtained here by stripping off everything above the surface of the bed and quarrying the coal in an open cut.

† The Loyalsock Coal Field in Sullivan County has been reported by Mr. Frank-

COAL PRODUCTION.

No collection of statistics, extending over any term of years, of the production of any of the numerous minerals mined in Pennsylvania, has ever been made by either the State or National Government, so that, of the many tables which have been compiled and reported by different individuals, one is at a loss to know which to accept as the most authentic.

The State Department of Internal Affairs has organized a "Bureau of Industrial Statistics," which, under the efficient and intelligent management of Mr. M. S. Humphreys, has already published several very valuable annual reports. The means at the command of this department are too restricted, and the laws compelling mining operators to make regular and correct returns are too lenient to enable Mr. Humphreys to make his reports as complete and as valuable as those annually made by the Mining Record Office of England, under the charge of Mr. Robert Hunt, F.R.S. The question of the increased production and ultimate exhaustion of the anthracite fields is becoming a more important one to the State every day, and provision should be made by the legislature for a careful and complete collection of the statistics connected with the production and shipment of all our mineral products, of which coal (anthracite and bituminous), iron and petroleum* are the principal. Many valuable facts connected with the production of anthracite are at present collected and reported by the mine inspectors. They are, without doubt, the most detailed and reliable of any which are available to the public. In general results, however, they differ very much from those reported by the Bureau of Industrial Statistics, and by Mr. John H. Jones, who receives directly from the transporting companies the amount of their shipments. For instance, the following table shows the tonnages for 1881, variously reported.

	Tons.†
Total production, Bureau of Statistics,	27,929,128.18
Total shipment, mine inspectors,	29,525,909
Total production, mine inspectors,	30,537,581

lin Platt, Geologist of that county, to contain a soft anthracite coal of a peculiar character, instead of bituminous coal, as was formerly supposed. I have made no examination or survey of this field yet, but expect to do so before the completion of the work.

* No statistics of petroleum are collected directly by State authority; those published by the Bureau of Industrial Statistics are taken from Stowell's Petroleum Reporter, and their accuracy is very much questioned by a large number of oil producers.

† The ton used in this paper is 2240 pounds.

	Tons.
Total shipment, John H. Jones, ...	28,500,017
Total shipment, R. P. Rothwell, editor *Engineering and Mining Journal*, ...	27,208,524
Total production, R. P. Rothwell, ...	30,261,940

These figures are certainly conflicting, and it is difficult to know which estimate to accept. It would be advisable if the collection of these statistics could be made by the State in conjunction with the Geological Survey as it is done in England, and as it has been proposed should be done in some sections of the United States by the United States Geological Survey. The State Geological Survey will make measurements and calculations in order to estimate as nearly as possible the total amount of coal contained in the different basins, but it is not called upon or expected to collect statistics of production.

I have, examined with considerable care, the different tables which have been compiled to show the past production of the anthracite region, and the one which has been adopted by the Survey, and which will be published in the first volume of the *Anthracite Survey Reports*,* is the one which has been compiled by Mr. P. W. Sheafer,† of Pottsville, which shows the shipment of anthracite coal from 1820 to 1868 inclusive. Since 1868 the statistics which have been accepted, are those reported by Mr. John H. Jones, confidential accountant of the anthracite transporting companies.

The rapid growth of the shipment of coal is shown by the following statistics for every tenth year:

Schuylkill Region.			Lehigh Region.		Wyoming Region.		
Years.	Tonnage.	Per cent.	Tonnage.	Per cent.	Tonnage.	Per cent.	Total.
1820			365				365
1830	89,984	51.50	41,750	23.90	43,000	24.60	174,734
1840	490,596	56.75	225,313	26.07	148,470	17.18	864,379
1850	1,840,620	54.80	690,456	20.56	827,823	24 64	3,358,899
1860	3,749,632	44.04	1,821,674	21.40	2,941,817	34.56	8,513,123
1870	4,968,157	30.70	3,239,374	20.02	7,974,660	49.28	16,182,191
1880	7,554,742	32.23	4,463,221	19.05	11,419,279	48.72	23,437,242
1881	9,253,958	32.46	5,294,676	18.58	13,951,383	48.96	28,500,017
Total to end of 1881.	173,864,384	39.64	83,231,131	18.98	181,484,879	41.38	438,580,394

* Volume I, Southern Coal Field, Panther Creek Basin.

† Mr. Sheafer, for a number of years, was connected with the First Geological Survey, and since its completion, in 1841, has resided in the coal region at Potts-

The Schuylkill region includes the Western Middle Coal Field, and that portion of the Southern Coal Field west of Tamaqua. The Lehigh region includes the Eastern Middle Coal Field, and that portion of the Southern Coal Field east of Tamaqua, known as the Panther Creek Basin. The Wyoming region is equivalent to the Northern Coal Field. This table represents the total shipment of coal away from the region, and does not include the amount of coal consumed within the region. This amount has hitherto been variously estimated at from 8 to 10 per cent. of the total amount produced. Although the amount of coal burned within the coal-fields has increased from year to year, yet the percentage of the total amount mined, which has been so used, has unquestionably diminished at the same time. The total shipment, according to Messrs. Sheafer and Jones, up to the end of 1881, has been 438,580,394 tons, and if to this we should add 9 per cent. for local consumption, the grand total would be 478,052,629 tons. During 1881 the mine inspectors gave this question careful consideration, and according to their estimates, given below, the amount consumed in the region during that year, was about 5½ per cent. of the total amount produced.

It is hard to appreciate the enormous amount of anthracite which has already been mined. Assuming that a ton of coal of 2240 pounds in the bed contains 25 cubic feet, 478,052,629 tons would form a solid wall 100 feet wide and 100 feet high for a distance of 226 miles, or it would form a solid wall along the line of the Pennsylvania Railroad, between Philadelphia and New York, 100 feet wide and over 250 feet high.

The following table, compiled from the mine inspector's reports, shows the number of working collieries in the region, as divided by Mr. John H. Jones during 1881, with the total amount of coal shipped from each district,* and the amount produced by the largest colliery in each district.

* Mr. Jones's division of the region has been provisionally accepted by the Geological Survey.

District.	Number of working Collieries reported.	Largest producing Colliery, and total production for 1881.		Total shipment of Districts, 1881.
	NORTHERN COAL FIELD.			
Carbondale, . . .	18	Coal Brook,	220,639	1,684,522
Scranton, ...	31	Capouse,	276,840	3,846,505
Pittston, ...	32	Exeter,	209,000	1,988,015
Wilkes-Barre, . .	49	Nottingham,	371,198	6,812,505
				14,331,547
	EASTERN MIDDLE COAL FIELD.			
Green Mountain, .	5	Upper Lehigh No. 4,	169,833	420,764
Black Creek, . . .	20	[illegible] No. 2,	266,734	2,176,854
Hazleton, ...	14	[illegible],	154,072	1,279,577
Beaver Meadow, .	10	Honeybrook, No. 4,	164,940	1,116,913
				4,993,908
	WESTERN MIDDLE COAL FIELD.			
East Mahanoy, . .	16	Ellangowan,	240,977	1,261,102
West Mahanoy, . .	57	William Penn,	222,252	4,532,916
Shamokin, . . .	17	Big Mountain,	178,959	1,410,830
				7,204,848
	SOUTHERN COAL FIELD.			
Panther Creek, . .	10	Breaker No. 8,	140,365	742,027
East Schuylkill, .	21	New Boston,	153,924	541,246
West Schuylkill, .	23	Thomaston,	82,975	478,161
Lorberry, ...	5	Rausch Creek,	85,382	148,967
Lykens Valley, . .	6	West Brookside,	374,533	1,085,205
				2,995,606
	Total shipment, 1881,			29,525,909

Total Shipment and Production of Mine Inspectors' Districts.

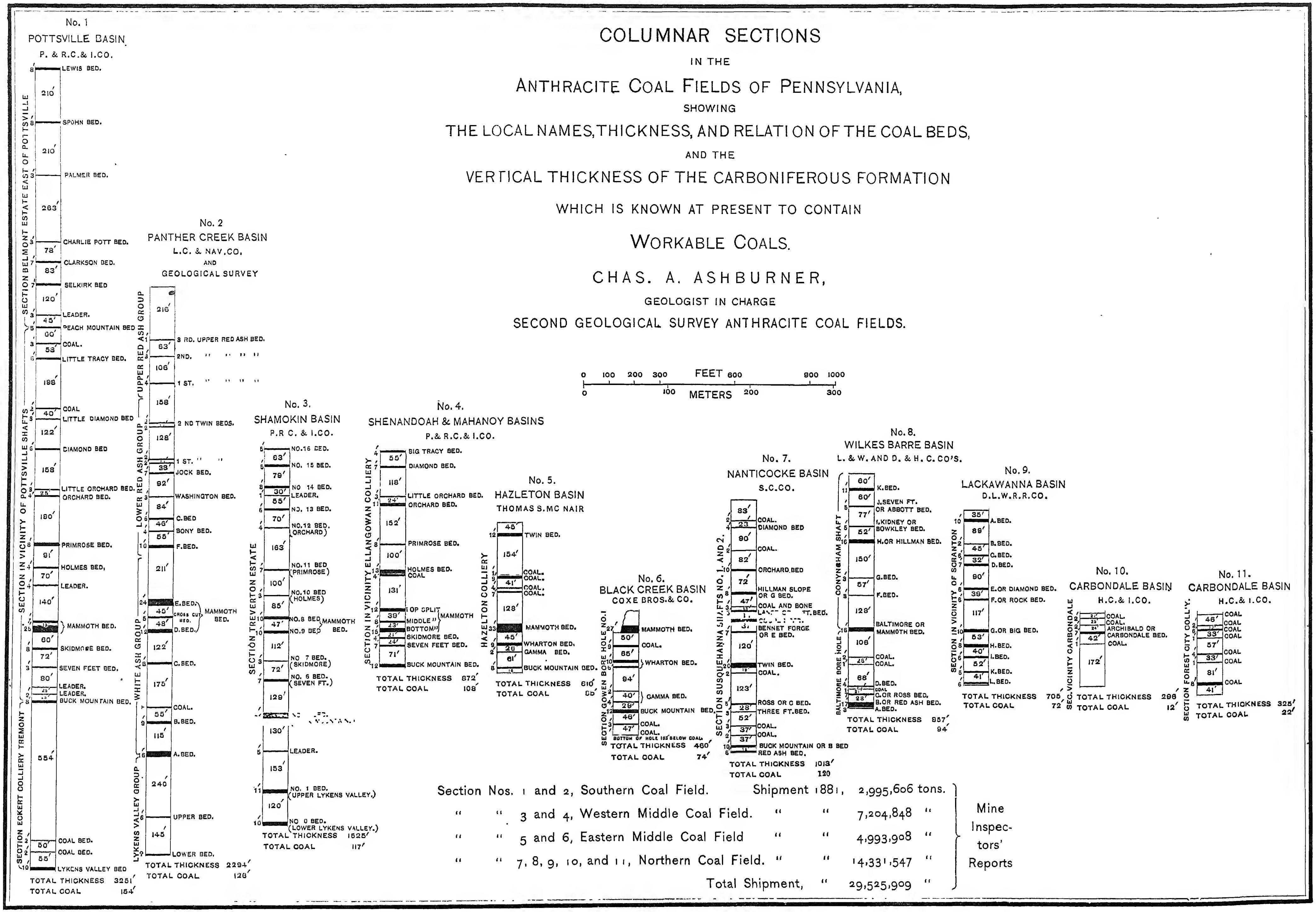
District.	No.	Inspector.	Shipment.	Mine consumption.	Total.
First Schuylkill, .	1	Samuel Gay,	1,726,069	103,566	1,829,635
Second "	2	Robert Mauchline,	4,248,666	254,980	4,503,646
Third "	3	James Ryan,	4,181,679	250,904	4,432,583
Middle { Carbon and Luzerne,	4	G. M. Williams,	7,021,505	not given.	7,021,505
Eastern	5	Patrick Blewitt.	7,310,042	402,222	7,712,264
Southern	6	James E. Broderick,	5,037,948	not given.	5,037,948
Totals, ...			29,525,909	1,011,672	30,537,581

The production of the Loyalsock Coal Field in Sullivan County, which has been included in the anthracite district, has been given by Mr. Rothwell in his inaugural address at this Meeting.*

The occurrence of anthracite in Sullivan County is quite different from its occurrence anywhere else in Pennsylvania. The anthracite bed there lies nearly horizontal, and contains about 5 feet of coal, producing on analysis: (A. S. McCreath.)

Water, ...	1.295
Volatile matter, ...	8.100
Fixed carbon, ...	83.344
Sulphur, ...	1.031
Ash, ...	6.230
Total, ...	100.000

* This volume, page 6.


COLUMNAR SECTIONS
IN THE
ANTHRACITE COAL FIELDS OF PENNSYLVANIA,
SHOWING
THE LOCAL NAMES, THICKNESS, AND RELATION OF THE COAL BEDS,
AND THE
VERTICAL THICKNESS OF THE CARBONIFEROUS FORMATION
WHICH IS KNOWN AT PRESENT TO CONTAIN
WORKABLE COALS.
CHAS. A. ASHBURNER,
GEOLOGIST IN CHARGE
SECOND GEOLOGICAL SURVEY ANTHRACITE COAL FIELDS.
FEET 0 100 200 300 600 800 1000
METERS 0 100 200 300
No. 1 POTTSVILLE BASIN P. & R.C.& I.CO.
TOTAL THICKNESS 3251′
TOTAL COAL 154′
No. 2 PANTHER CREEK BASIN L.C. & NAV.CO. AND GEOLOGICAL SURVEY
TOTAL THICKNESS 2294′
TOTAL COAL 128′
No. 3. SHAMOKIN BASIN P.R C. & I.CO.
TOTAL THICKNESS 1525′
TOTAL COAL 117′
No. 4. SHENANDOAH & MAHANOY BASINS P.& R.C.& I.CO.
TOTAL THICKNESS 872′
TOTAL COAL 108′
No. 5. HAZLETON BASIN THOMAS S.MC NAIR
TOTAL THICKNESS 610′
TOTAL COAL 55′
No. 6. BLACK CREEK BASIN COXE BROS.& CO.
TOTAL THICKNESS 460′
TOTAL COAL 74′
No. 7. NANTICOCKE BASIN S.C.CO.
TOTAL THICKNESS 1013′
TOTAL COAL 120
No. 8. WILKES BARRE BASIN L. & W. AND D. & H. C. CO'S.
TOTAL THICKNESS 957′
TOTAL COAL 94′
No. 9. LACKAWANNA BASIN D.L.W.R.R.CO.
TOTAL THICKNESS 706′
TOTAL COAL 72′
No. 10. CARBONDALE BASIN H.C.& I.CO.
TOTAL THICKNESS 296′
TOTAL COAL 12′
No. 11. CARBONDALE BASIN H.C.& I.CO.
TOTAL THICKNESS 325′
TOTAL COAL 22′
Section Nos. 1 and 2, Southern Coal Field. Shipment 1881, 2,995,606 tons.
" " 3 and 4, Western Middle Coal Field. " " 7,204,848 "
" " 5 and 6, Eastern Middle Coal Field " " 4,993,908 "
" " 7, 8, 9, 10, and 11, Northern Coal Field. " " 14,331,547 "
Total Shipment, " 29,525,909 "
Mine Inspectors' Reports

Sixty feet vertically under this bed is found a bed of true bituminous coal. The anthracite is a valuable coal, especially for domestic uses. This field, with the peculiar and exceptional occurrence of anthracite and bituminous coal, one directly above the other, demands a careful and thorough examination by the Geological Survey of the anthracite coal fields.

THE PRACTICAL METALLURGY OF TITANIFEROUS ORES.

BY WILLIAM M. BOWRON, SOUTH PITTSBURG, TENN.

In the hope that a brief description of the conditions that are favorable or unfavorable to success in the practical treatment of titaniferous ores in the blast-furnace may not be without interest to the members of the Institute, the present paper is submitted.

The class of ores of which I speak may be described as magnetites, with a gangue of siliceous matter, in which a portion of the silica is replaced by titanic acid. Professor Dana, in his *System of Mineralogy*, gives a long list of representative analyses of titanic iron ore in which the percentage of titanic acid varies from 59 down to 3½. If the percentage is below the latter figure, the ore is no longer recognized as a "titanic ore;" although, according to my experience, titanic acid is present, in small quantities, in almost all ores. In the methods followed in ordinary analysis it is usually included with the "insoluble matter," unless special search is made for it. In the ores usually regarded as "titanic" the proportion of titanic acid frequently assumes *quasi* definite percentages, such as from 4 to 5, 8 to 9, 12 to 13, and so on, in an ascending scale to those higher percentages that do not at present concern us. The proportions quoted characterize large masses of ore that are now accessible to market and are lying idle only on account of the titanic stigma.

My experience with titanic acid in the furnace began in England, fourteen years ago, with my being employed as chemist by the manager of the Norwegian Titanic Iron Company, which was at that time smelting, without mixture, ilmenite from Norway in a furnace 16′ × 50′. The process, regarded as a process, was a perfect success; but the enormous quantity of fuel required, the small quantity of iron in the ore, and the cost and uncertainty of importation militated seriously against its commercial success, and a few years saw the attempt abandoned. The metallurgy being, successful, an at-

tempt to trace the process becomes interesting. The composition of the ore was as follows:

Titanic acid,	39.20
Sesquioxide of iron,	18.59
Protoxide of iron,	30.00
Oxide of manganese,	.60
Alumina,	2.89
Magnesia,	2.80
Silica,	5.70
Loss,	.22
	100.00

The ore was filled into the furnace in charges of about a ton, together with from 17 cwt. to a ton of coke and 15 cwt. to 18 cwt. of fluxes, consisting of, say, 12 cwt. of limestone and 3 cwt. to 4 cwt. of basalt, old red bricks, or any similarly fusible silicate.

The following is an analysis of the limestone used at the time I was there:

Silica,	.95
Alumina,	.40
Lime,	54.60
Magnesia,	.43
Carbonic acid,	43.42
	99.80

One analysis of the red bricks used at the same time gave:

Silica,	59.60
Alumina,	24.32
Sesquioxide of iron,	10.88
Lime,	2.33
Magnesia,	trace.
Water and loss,	2.87
	100.00

The coke contained from 3 to 7 per cent. of ash, the composition of which is indicated by the following analysis:

Silica,	50.21
Alumina,	44.88
Sesquioxide of iron,	3.36
Lime,	.09
Magnesia,	trace.
Sulphur,	.11
Phosphoric acid,	trace.
Alkalies,	not estimated.
Loss,	1.35
	100.00

The composition of the cinder was:

Silica,	27.83
Titanic acid,	36.18
Alumina,	9.18
Protoxide of iron,	1.86
Lime,	24.36
Magnesia,	.60
Alkalies,	not estimated.
	100.01

We here have analyses of the materials used, and, although the charges were ascertained approximately by personal observation, it may be well to verify them, especially as an attempt at secrecy was maintained. A close fence was built around the pig beds, etc., the scales were adjusted with a privately known error, and the blast-gauge showed several pounds pressure when the engine was at rest. The materials that went into the furnace, and the cinder and iron that came out were, however, accessible, and their compositions, except that of the iron, are given above. If we take, as a hypothetical charge,

Coke, with, say, 5 per cent. of ash,	2240 lbs.
Ore,	2240 "
Limestone,	1200 "
Bricks,	500 "

the cinder-making materials, on the basis of the analyses given above, will be as follows: From the

		Silica.	Titanic acid.	Lime.	Alumina.	Magnesia.
Ash in the coke,	112 lbs.,	56.23		0.10	50.26	
Ore,	2240 "	127.68	878.08		64.73	62.72
Limestone,	1200 "	11.40		655.20	4.80	5.16
Bricks,	500 "	298.00		11.65	121.65	
Total,	4052 lbs.	493.31	878.08	666.95	241.44	67.88

The theoretical composition of the cinder, provided the charge is correctly given and the analyses properly represent the composition of the materials used, compares as follows with the actual composition, as found by analysis:

	Theoretical.	Actual.
Silica,	21.01	27.83
Titanic acid,	37.40	36.18
Lime,	28.41	24.36
Alumina,	10.29	9.18
Magnesia,	2.89	.60
	100.00	98.15

The similarity between the theoretical cinder and the cinder actually produced is so close as to show that the charge assumed is a

good working charge, and that any change needed to suit the ore more closely would be indicated by the working of the furnace. The enormous consumption of fuel, which is, roughly speaking, three tons of fuel to one ton of iron produced, is made necessary by the immense body of cinder required to remove such a large quantity of titanic acid.

Turning now to ores of more frequent occurrence in the Atlantic States, the following are analyses, taken at random from my note-book:

Locality.	SiO_2.	TiO_2.	Fe.	Analyst.
North Garden, Va.,	10.97	6.53	52.52	?
Westport, Lake Champlain, N. Y.,	5.89	4.58	61.75	?
Centre County, N. C.,	1.50	8.65	60.88	Fesquet.
Guilford County, N. C.,	.75	12.08	58.24	Britton.
Roan Mountain, Mitchell County, N. C.,	3.66	5.33	65.44	Clarke.
Roan Mountain, Mitchell County, N. C.,	3.72	5.87	67.89	Genth.

The localities mentioned lie in a great ore belt that extends into Canada, and assumes, generally, larger proportions towards the northeast. Ores similar to these have been worked in Norway from the infancy of the iron trade in that country. Professor David Forbes, in the *Chemical News* for December 11th, 1868, gives his experience in dealing with ores of the following composition:

	No. 1.	No. 2.
Iron,	42.04	38.89
Oxygen, as loss,	16.03	14.84
Protoxide of manganese,	0.14	0.48
Alumina,	2.61	1.70
Lime,	2.11	3.55
Magnesia,	1.88	3.98
Silica,	19.90	28.10
Titanic acid,	15.10	7.10
Sulphur,	0.19	0.59
Phosphoric acid,	....	0.77
	100.00	100.00

No. 2 ore, on account of its proximity to the furnace, was used largely for the production of foundry iron, being too impure for bar iron. This ore, when charged alone for foundry iron, was found refractory, but a good liquid slag was produced when mixed with other ores free from titanic acid.

Professor Forbes says: "The experience of the Scandinavian iron-masters has shown that the only objection to the use of titaniferous ores is that they are found to be more and more refractory in the furnace in proportion as they contain a larger proportion of titanic acid; and if much titanium is present they require so much larger an amount of charcoal to smelt them as not to render their employment profitable in a country where other ores, free from titanium,

can be obtained at a reasonable rate. After considerable experience in smelting the above ore, which yielded a very good iron, it was found unprofitable to smelt it alone for the above reason, but its use was found beneficial when employed in about equal proportions with the other ores of the district that were free from titanium.

"In the attempt to cause it to smelt more easily, my predecessor, under the supposition that a volatile compound of silicon and titanium would be formed, fluxed this ore with gradually increasing charges of stamped quartz, until at last an iron was obtained so highly charged with silicon that it flowed from the furnace like porridge. I, on the contrary, used lime as a flux, and probably went to the other extreme, with the object of slagging off the titanic acid as titanate of lime, but I did not obtain a satisfactory result. Subsequently, however, the examination of some silico-titanates, which proved more fusible than pure titanates, led me to employ a mixture of limestone and stamped quartz as a flux. This was found satisfactory in practice, and when the amount of titanium did not exceed 8 per cent. no difficulty was found in working this ore cleanly and profitably. . . . . The furnace in which these ores were worked was 32 feet from sole of furnace to charging plane, and 7 feet bosh."

The charcoal was soft fir (pine) and it took about 3750 pounds to make a ton of iron, or about one-fifth more than is used for a ton of iron in the most economical districts in this country, for the ton is 2240 pounds. The blast was heated to about 500° F., and the yield was about sixteen tons per week, or about half what such a furnace should turn out in this country.

The small height of the furnace and the softness of their coal furnish an explanation of this small yield. Professor Forbes does not mention the pressure of blast, but three-quarters of a pound is usually about the mark in that district. His experience in fluxing is what might have been expected, as *perofskite*, the titanate of lime found in nature, is practically infusible, while the mineral *titanite*, the silico-titanate of lime, is fairly fusible. A study of minerals seems to point to the fact that those that contain titanic acid and magnesia together in quantity are usually refractory and infusible.

Where these ores have been tried in furnaces that were smelting other ores of a non-titaniferous character, and difficulties have been caused by their hanging and beginning to build on, relief has usually been sought by increasing the heat, and, after considerable annoyance, the ore has been discarded. The whole secret of working these ores successfully and continuously is to keep the heat so low as just to reduce the iron and not reduce the titanic acid. The iron

will be white, or, at best, mottled, if there is much titanic acid to contend with. Titanic iron is essentially a forge iron. Foundry iron can only be produced when the titanium is low, and then only by making a large quantity of cinder, so as to "wash" the titanic acid out of the furnace. This, of course, is at the expense of fuel, and the tendency to obstruct the hearth is intensified. Such iron was made in Forbes's furnaces only for special purposes at long intervals, and in small quantity. Silicic and titanic acids are reduced in the furnace at about the same temperature, and a furnace that can make iron under an acid cinder, and keep the silica out, will not be troubled with titanium deposits.

If, then, the use of titaniferous ores involves extra fuel, low heats, and slow driving, and makes white iron, what is the inducement to use them? I can only answer, that for ordinary use they are wholly unsuitable; but for making a forge iron, that has brought double the market price of common iron, for use as a mixture to impart the property of cold toughness to other iron, or for making an iron to be mixed with other irons that are not quite up to requirements for boiler plates, for blooms, or for an extra good iron, generally, these ores are most valuable.

The details of furnaces for smelting these ores are like those suitable for ordinary magnetite;—a small crucible, low tuyeres, a high narrow upper hearth, and flat boshes, are the most important; large tuyeres, a low, slack blast, and an acid fusible cinder, are also necessary. Anything further that the furnace needs to suit the special ore under treatment will appear in the working. The above directions will do for ores, as Forbes says, containing up to 8 per cent. of titanium, or, say, 13 per cent. of titanic acid. If the percentage is higher than that, special precautions, not necessary to dwell on here, must be taken. If from any cause the furnace *has* reduced the titanic acid, and is in a choked condition, the readiest modes of relief consist in throwing off the ore that caused the trouble, substituting a non-titaniferous ore and, when procurable, gray blast-furnace cinder from non-titaniferous ores, and raising the heat.

The analyses given above have been taken from my note-book. They were made by various analysts, whose names, in many cases, are not recorded. The analysis of Norton* cinder, I recently confirmed by analyzing a small sample that I took personally, and have had in my cabinet for fourteen years.

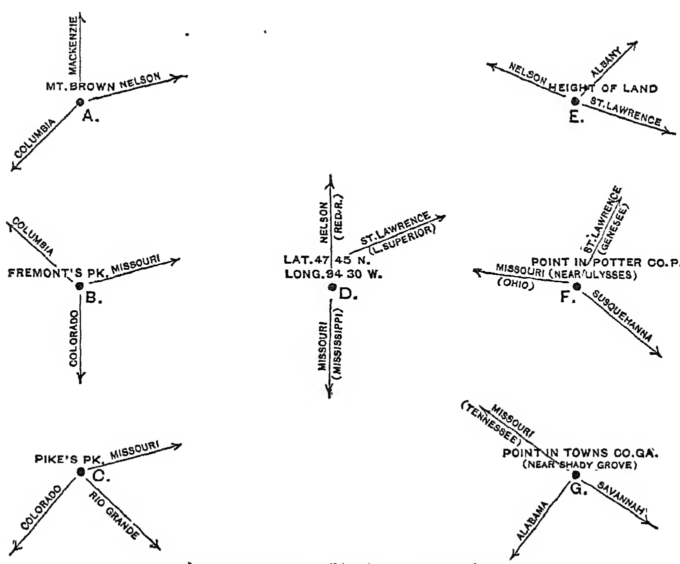
* The works of the Norwegian Titanic Iron Co. were at Norton, near Stockton-on-Tees, England.

NOTES ON THE GEOLOGY AND MINERALOGY OF SAN JUAN COUNTY, COLORADO.

BY THEODORE B. COMSTOCK, SILVERTON, COLORADO.

The existing topographical features of the United States present many points of interest to the student of dynamical geology, but there is, perhaps, no subject which offers a more promising field for investigation than the relations between the geological structure and the mineralogical characteristics of the principal mining districts.

There are seven prominent culminating points in the relief of North America, each one of which can be used as a type of the physical features of all the others. Again, if we divide these seven elevated districts into two sets, we shall discover a still more striking parallelism between the individual members of each group. But the most remarkable revelation is the fact that each one of these points



A:-N.W. Area. B:-W. Area. C:-S.W. Area. D:-Central Area.
E:-N.E. Area. F:-E. Area. G:-S.E. Area.

is more or less closely the centre of an area of economically important mineral resources. It is interesting to note in this connection that six of these mineral tracts lie mainly within the borders of the United States, three of them being almost wholly in our territory. For

purposes of reference it will be convenient to arrange the seven apices (or continental pinnacles) in the form of a diagram, as above.

A somewhat detailed personal examination of the geology and topography of districts B, C, D, and E on the ground, in addition to field studies in a considerable portion of the drainage area of districts F and G (extending over a period of fifteen years), has brought to my attention some curious facts, which I can simply mention in this place.

1. Notwithstanding the enormous dynamical effects produced by the flexures of the earth's crust and by extensive outflows of molten material, the results of aqueous erosion are even more apparent in the present topography of our country. As instances of this feature may be cited the remarkable gorges of the Columbia and Colorado rivers and their tributaries; the former channels of numerous streams now deserted, and in many cases silted up to great depths with sand and gravel; the vast deposits of rearranged drift material covering large areas in the basins of the great lakes; the chasm of the Niagara River; and many very interesting examples that are afforded by the channels, past and present, of the Ohio, Tennessee and other rivers.

2. The seven continental pinnacles have been subjected to greater geological changes than most other portions of the continent, and nearly the whole of the American geological record is comprised in the rocks of these areas taken together. Certainly not far from the pinnacles A, B, C, D, E, and G, and within the drainage area of F, are to be found fair exposures of the lowest known sedimentary strata, of Eozoic age, accompanied by representatives of each succeeding age to the most recent period, arranged in concentric rings, at greater or less distances from the Archæan core, in each case. These pinnacles have, therefore, been to all intents and purposes the primary centres of elevation of the North American continent, about which all subsequent geological history has been grouped. To go a little further in this preliminary review, it may be observed that each pinnacle has attached to itself a distinctive feature marking a special culmination of one prominent era in geologic time. In other words, districts D and E are characteristically Archæan, F is pre-eminently Palæozoic, as is also the northern portion of area G, while the Mezozoic and Tertiary eras have left their strongest impress upon the regions culminating in A, B and C. The last or modern era is best recording its history in the southern portion of G, the most incomplete hydrographic basin, which has yet to receive its greatest development.

3. Each pinnacle (except the southeastern) is the source of one prominent river system of its own, and also helps to form two other systems in connection with the adjoining pinnacles.

4. The central pinnacle is the source of no *distinct* river system, but forms a part of three drainage areas, each of which is fed by two adjoining pinnacles.

5. The southeastern pinnacle, forming the culminating point in the drainage of an area now emerging from the sea, is exceptional to some extent.

6. The continental divide in the neighborhood of each pinnacle is rarely the axis of the fold of the strata at that point.

7. The headwaters of the several systems approach very closely in the vicinity of the pinnacles (as at Two Ocean Pass, Wyoming Territory; the divide between the Susquehanna and St. Lawrence, in Tompkins County, New York; and elsewhere).

8. The present drainage at these points is usually the reverse of the course during the glacial period.

9. Other homologies are apparent, which may readily be discerned by an inspection of the diagram in connection with a good drainage map of the United States.

The district which I shall discuss in this paper includes a portion of the drainage system of the southwestern area (C) of the diagram. San Juan County embraces but a portion of the hydrographic basin of one branch of the Colorado River, including all the upper ramifications of the Animas, with small areas at the sources of the Rio Grande and of branches of the Gunnison River. The boundaries of the county are not such as would be chosen by a geological or topographical surveyor, nor yet wholly from economical considerations, but were selected largely with reference to the convenience of settlers at the date of adoption. The lowest point in the county (about 8500 feet above sea-level) is near the middle of the southern line, where the Animas River crosses over into La Plata County. The highest points are two peaks, one of the Needles near the southeastern corner (13,975 feet), and Niagara Mountain, near Eureka (13,790 feet). From its source in the extreme northeastern portion to its exit from the county, the Animas River falls 4100 feet, or an average of 117 feet to the mile. But the grade from its source to Eureka, a distance of $6\frac{1}{2}$ miles, averages 444 feet; from Eureka to Howardsville, 4 miles, the descent is 50 feet to the mile; from Howardsville to Silverton, 5 miles, only 22 feet to the mile; and from Silverton to the county line, about 45 feet to the mile.

Other topographical features may best be understood by reference to the accompanying map, which covers enough of the adjoining counties to show the drainage accurately.

There are very few sections of equivalent area which present as much of thrilling interest as this little county of San Juan, either to the cursory observer or the profound investigator.

The county has an area of only 405 square miles, and one-sixth of the whole area is located as lode claims alone, aggregating over *one thousand miles* of fissure veins, or an average of one full claim of 1500 feet to each man, woman, and child in the county. Allowing for a development of only one-tenth of the claims to the depth of 500 feet, with the exceedingly low estimate of 6 inches average width of ore-streak, and a yield of only thirty dollars per ton, all told, we get an annual productive capacity of *five millions of dollars* through a period of *one hundred and twenty-eight years.**

Marvellous as this statement may appear, it is not expanded; but it expresses briefly what resources nature has placed here, within the reach of human industry properly applied. It will be my aim in this paper to explain, so far as I am able, where and in what manner these enormous riches have been deposited, and by what means they have been prepared for utilization at the hand of man.

One unaccustomed to the minute study of geological features might spend much time in this county, and gain a very fair knowledge of the veins, without suspecting the existence at the surface, anywhere in the county, of any but the volcanic series of rocks. But a detailed study of the county, such as is possible only to one who devotes all his time to the subject for several years, enables one to recognize many features of great scientific and economic interest. Passing up the Animas River from the mouth of Cascade Creek, a section is obtained which includes the tilted granites and slates of the metamorphic series, overlaid by limestones of Devonian age, which crop out in connection with earlier sandstones, not far below Silverton. But the best sections of the limestone strata are to be obtained further west, in the cañon of Cascade Creek. The Animas Cañon section is far from satisfactory by itself, on account of the tortuous course of the gorge rendering it difficult to retain in mind the trend of the uplift. The strike is generally transverse to the stream, but the thick covering of volcanics, with the abundant talus, often obscures the underlying beds.

At Silverton two large streams flow into the Animas, forming one of the finest parks in the region. Mineral Creek and Cement Creek

* I take advantage of an opportunity to revise this paper, to state that the shipments of gold and silver ores from Silverton from July 17th, 1882, to December 31st, 1882, aggregated $650,000, from no more than thirty or forty veins, each averaging less than 1000 feet of shaft and levels, all told.

both head in the volcanic belt, but the nature of the rock is such as to render erosion less difficult than in other portions of the district. As a consequence, large deposits of bog iron have been made along the banks, especially in portions of Cement and Mineral creeks. The source of these accumulations may readily be ascertained, for the whole of the divide between the two creeks, for ten or twelve miles, is one vast mass of the characteristic red and yellow rocks from which the names Red Mountain and Yellowstone Mountain have been derived.* A somewhat irregular outcrop of this character may be traced from this point across the head of the South Fork of Eureka Gulch to a point south of Eureka and east of the Animas River; thence over to the divide between Lake Fork and Henson Creek, in Hinsdale County. Similar exposures may be seen along the walls of the cañon of Mineral Creek, and upon some of the tributaries of that stream, as notably upon the southern side of Snow-shoe Gulch. A very rich and well-defined belt of mineral veins follows approximately the same course, but there are many points in the tract where careful prospecting has been very little rewarded. In fact, the highly-colored area itself may be regarded as a barren tract, to all intents and purposes, except in certain localities, where its topography is of a peculiar character, as in the new district of Red Mountain, which will be discussed beyond. This variegated area has been the most perplexing of all to myself since my studies here began, and it is only by the accumulation of facts from all parts of the region that I have been enabled to offer a satisfactory explanation.† The trend of the belt is nearly N. N. E., and follows closely the ridges between prominent gulches, crossing the continental divide near Eureka. The axis of the main Palæozoic uplift does not follow the line of this outcrop, but bears considerably more to the eastward, crossing the colored belt on Engineer Mountain, outside the limits of San Juan County. Still more puzzling, at the first view, is the very noticeable fact that neither of these lines is strictly coincident in direction with the courses of all the most prominent veins of the county.

The general course of the red and yellow belt is N. 50° E., while the trend of the nearly buried Palæozoic folds is about N. 80° E. Below are given approximately the bearings of a fair average of the

* As explained further on, I have good reason to connect these deposits with the action of hot-springs, but the original source is no doubt the highly-colored strata originally impregnated with pyrite.

† The following quotations from the report, etc., of Dr. Hayden, will be interesting in this connection.

best exposed veins in different parts of the county, compiled from official surveys for patents:

NAME.	LOCATION.	COURSE.	REMARKS.
Saxon,	Poughkeepsie Gulch.	N 44° 30′ E N 65° 30′ E N 72° E N 56° 15′ E	
Maid of the Mist,	" "	N 32° 45′ E N 63° 51′ E	
Bonanza,	" "	N 76° 5′ E	
Mobile,	" "	N 84° 15′ E	
Alabama,	" "	N 38° 15′ E	
San Antonio,	" "	N 40° 30′ E	
Pagosa,	" "	N 46° E	
Little Discovery,	" "	N 64° 15′ E	
Amador,	" "	N 86° E	
Tyrol,	" "	N 33° 5′ E	
Columbus,	Upper Animas.	N 58° 10′ E N 63° 16′ E	
Empire State,	" "	N 45° E	
Excelsior,	" "	N 33° 25′ E	
Tom Moore,	" "	N 33° 50′ E	
Cashier,	Eureka.	N 79° E S 65° 25′ E	
Cuba,	"	N 79° 30′ E	
American,	"	N 80° E	
Belmont,	Burns's Gulch.	N 35° 30′ E	
Almont,	" "	N 35° E	
Sioux City,	" "	N 0° 40′ W	
Cynic,	" "	N 26° W	
Rocky Mountain Chief,	" "	N 73° 45′ E	
Denver Bell,	" "	N 15° 15′ E	Crosses Rocky Mountain Chief.
Whale,	" "	N 17° 3′ E	" " "
Silver Wing,	" "	N 48° 27′ E	
Veta Madre,	Stony Gulch, (Galena Mt.)	N 39° W	
Summit,	" "	N 5° W	Crosses Veta Madre.
Lookout,	Cunningham Gulch,	N 37° 30′ W	
Oriental,	" "	N 28° 35′ W	
Trail,	" "	N 25° W	
Aquila,	" "	N 23° 38′ W	
Regulator,	" "	N 25° W	
Pride of the West,	" "	N 20° 30′ W	
Philadelphia,	" "	N 3° 42′ E	
Green Mountain,	" "	N 24° 50′ W	
Flat Broke,	" "	N 10° 50′ W	
Highland Mary,	" "	N 43° 15′ W N 53° 09′ W N 69° 30′ W	
Wm. N. Nichols,	" "	N 49° 27′ W N 36° 18′ W	Extension of Highland Mary.
Robert Bruce,	" "	N 50° W N 69° 47′ W	
Royal Tiger,	" "	N 62° 9′ W N 72° W	
No. 1,	" "	N 4° 27′ E	Crossing Highland Mary.
No. 3,	" "	N 4° 37′ E	
General Garfield,	Arrastre Gulch.	N 21° W	
Peerless,	" "	N 36° 28′ W	
Hidden Treasure,	" "	N 15° E	
Jennie Parker,	Near Silverton.	N 45° 53′ W N 35° 24′ W	
Cleveland,	Below Silverton.	N 17° 53′ W	
Great Eastern,	Sultan Mountain.	N 35° 30′ E	
Mattie,	Cement Creek.	N 35° W	
Fletcher,	" "	N 15° W	
Los Angelos Star,	" "	N 15° W	
Storm,	" "	N 30° W	Anvil Mountain.
Ellen,	" "	N 30° W	" "
Copper Clad,	" "	N 15° W	
Andrews,	" "	N 15° W	
Block Silver,	Engineer Mountain.	N 38° E	
Eastern Star,	" "	N 34° 15′ E N 49° 15′ E	
Wair,	" "	N 16° 35′ E	
Humboldt,	" "	N 51° 6′ E	
Philadelphia,	" "	N 11° 10′ E	

A careful perusal of the foregoing table and the map, in connection with much field study, leads to the following interesting deductions:

1. There is no regular course or bearing to which the veins of San Juan County can be referred as a primary or principal trend.

2. The variations in direction in each district are numerous, and the veins are grouped about the prominent peaks in a radiating manner.

3. The sources of the minor streams flow down between the veins, forming the so-called side gulches, but the augmented creeks cut through the veins, as a rule.

4. All the prominent or primary veins trend east of north in the northern part of the county, and west of north in the southern portion.

5. The secondary veins, of later date than the primary veins (which have been broken by the former), radiate from certain prominent peaks, but not from all.

6. The primary series of veins in all parts of the county north of the Grand Cañon of the Animas bear towards one point, viz.: Red Mountain Peak, near the head of Cement and Red creeks.

7. A line connecting the head of Arrastre and Cunningham Gulches and the peak of Red Mountain (bearing about N. 65° W.), marks the central trend, along which belt the veins are practically vertical, while the hade of the veins north and south of this line is usually oblique to this perpendicular, as if bearing in depth towards a common central area of eruption or vein formation. Possibly the superabundance of gold in some of the veins along this course may not be unconnected with these facts.*

We are thus able to trace a wonderfully close connection between the existing topography and the trends of the veins, particularly in the northern half of the county. It is the veins which have induced the topographical features, however, as before explained. With each prominent peak as a special centre of radiation, there may be detected also a strong tendency among the bolder veins to group themselves about a central area. Of these facts I will speak more fully beyond.

Absence of Archæan Exposures.

We have no beds in this section that can, with any degree of pro-

* It must not be overlooked, however, that the gold is more characteristic of localities in which the vein exposures most nearly approach the metamorphic rocks, and this may after all be the true explanation of its preponderance along this line of outcrop.

priety, be referred to the Archæan era, and it is probable that over the whole of San Juan County the sea covered the land until the Silurian age was well inaugurated, and much later. From the small area over which the lowest beds in the district are exposed, it is very difficult to speak clearly of their history; but the facts are rather against the occurrence of any early Palæozoic disturbance of the land.

The Upper Silurian Age and the Devonian Age.

These ages are probably represented by some of the beds exposed in the Grand Cañon of the Animas River, beginning at a point two miles below Silverton and extending about nine miles down the river. By a more recent uplift, these, and the overlying beds of known later date, were all tilted at high angles. This and other causes have so metamorphosed the strata that they must be grouped together somewhat indiscriminately as the *metamorphic series*, though they may be roughly divided into two groups, viz. (*a*) *the granites*, and (*b*) *the quartzites*. The former are not as well exposed as the latter, but they are sufficiently varied to suggest important differences in composition in the sedimentary beds from which they have been derived. As they do not form the surface rock over wide areas in our country, their mineral contents have been less investigated than those of any rocks in the district. The King mine and others on Sultan Mountain lie directly in the belt, but across the line of strike of the fold. The veins which crop out in this formation seem to lie in their original matrix, and at first sight might appear to have existed as such for a longer period than those inclosed in the more recent porphyry, but a careful examination of the structure of the formation affords abundant evidence that little or no disturbance of the strata occurred until a much later date than this of which we are speaking. Some very excellent veins occur in the quartzite belt in the Needle Mountains, and I have noticed "float" in the Animas Cañon, near Cascade station, that promises well for the discovery of gold-bearing lodes hereafter.

The metamorphic belt is exposed at intervals along a line which passes through Sultan Mountain, considerably south of west, near the head of Bear Creek, and east of north across the head of Cunningham Creek, thence out of the county near the western base of Handie's Peak. Its course between these points, as near the head of Arrastre Gulch, can be approximately traced by certain peculiarities of some of the prominent veins. As noticed in 1874 by Dr.

Endlich, the Little Giant (now Peerless) lode carries *chlorite*, a mineral characteristic of some of the metamorphic schists, which are elsewhere exposed along the belt, notably at the Highland Mary mine in Cunningham Gulch. In the Grand Cañon of the Animas below Silverton, southward to the county line, this group is exposed in considerable variety of texture, but without great differences in mineral composition. The granites vary from close-grained hornblendic gneisses to porphyritic binary masses. The schists are, perhaps, more frequently micaceous than the granites, but still more common are the micaceous sandstones shading into the quartzite group. Chloritic schists are prominent, and in some cases mica has evidently been replaced by the chlorite in separated beds of the same relative position.

The topography of the granitic area is, of course, less rugged and forbidding than that of the quartzite exposure, the former giving rise to hills more rounded and regular in outline.

Many of the metamorphics, especially those of later date, have been considerably altered by the outflow of volcanic material upon them. This cause, in connection with the previous metamorphism of the lower beds from beneath, has produced a marked effect upon Silurian and Devonian strata that would otherwise reveal more clearly their sedimentary origin. Dr. Hayden's party discovered a small outcrop of sandstone, probably referable to the Silurian, just beyond the county line on Lime Creek; and, in the limestone beds within the county limits, characteristic Devonian fossils have been found. This latter formation is exposed near the summit of the divide between Bear Creek and Cascade Creek, and along a line running parallelwise with the Animas Cañon, forming the cliffs along the sides of Lime Creek. It is again exposed at the head of the cañon below Silverton, in a workable stratum, which is employed as flux in the smelters, and for calcining to quick-lime. Another exposure occurs near the head of Cunningham Gulch, and the outcrop continues with interruptions and (probably) volcanic intrusions, across the country northward, near the eastern boundary of San Juan County, which it seems to cross not far from Eureka.

In some sections the relations of the limestone to the underlying metamorphic strata are so intimate that the two cannot readily be separated, and specimens may be obtained of limestone and granite united in one piece. This fact alone would be sufficient to prove the Palæozoic age of a large portion of the rocks of the metamorphic series.

Outside of this county, on Timber Hill, and northward in the

valleys of Lake Fork of the Gunnison and of Henson Creek, there are good exposures of both the granites and quartzites, which belong to the same or parallel folds. It is a fact of much significance, too, that the eastern limit of this metamorphic outcrop is practically the boundary of the area of fissure veins. Beyond this line, so far as yet explored, there is nothing of moment in the way of mineral veins until we reach a district of different character,—to all intents and purposes the scene of independent action.

The continental divide, though topographically pre-eminent, will be found to be almost wholly independent of all the main phenomena connected with the origin of our mineral resources. During the Silurian and Devonian ages, there seems to have been no sudden change of sea-level in this district, and certainly there could have been no foreshadowing of the course of the great Atlantic-Pacific watershed as it now exists. The rocks reveal to us only this picture of that ancient era: over the whole area of San Juan County there was a more or less quiet sea, probably in the earliest period somewhat more shallow and more like a series of low islands than it afterwards became. In other words, we have evidence of a gradual subsidence of the sea-bottom until the water became deep enough for the formation of beds of limestone, such as those we have just described. Where there are no exposures of these strata, evidences of their proximity are occasionally afforded by the existence of carbonate ores in some of the mines; as, for instance, in the Belcher and others upon Sultan Mountain, in Horse Thief Basin, and adjoining gulches.

At the close of the Devonian our district again became an area of gradual elevation, as shown by the deposition of shales and sandstones, which ushered in

The Carboniferous Age.

San Juan County has but comparatively small outcrops of the rocks of this age, and these occur chiefly in the southwestern portion. Some good sections can be had along the upper course of Lime Creek and Cascade Creek, as well as near the head of some of the southern branches of Mineral Creek. Though not coextensive with the Devonian series, the Carboniferous formation wherever it does exist, is almost invariably coincident with the limestone of the earlier age. The series consists of some 1200 feet of argillaceous, arenaceous, and calcareous beds, belonging to the Lower Carboniferous, covered by about 2000 feet of red sandstones of Upper Carbon-

iferous age. The lower sandstones are brownish or yellow, and contain fragments of plants. The limestones are blue, yielding well-known fossils. One of the best exposures of the red sandstone occurs on Bear Creek, beginning a short distance above its junction with Mineral Creek. Across the divide southward this formation again appears, underlaid, as along Bear Creek, by the blue limestones and lower sandstones and shales. An apparently local bed of conglomerate also occurs high up in the series, on Bear Creek, two and one-half miles above its mouth.

Beyond the limits of the county northward, eastward, and south ward, the strata of this group are better preserved, and the original connection of the various patches is much more readily traced. In one of these outcrops, or very closely associated with it, is the rich mineral deposit in Ouray County, near the northern line of San Juan, in which the Frank Hough, Eighth Wonder, and other well-known claims have been located. Another tract is at the surface in the neighborhood of Ouray, and some patches of intrinsic interest almost surround the town of Rico, in Dolores County. The Lime Creek and Cascade Creek outcrop spreads southward and a little eastward also, below Durango, and the great extent of the old Carboniferous sea, in which the whole was formed as one vast deposit, is shown by the great stretches of country over which it appears, far beyond the limits of our present sketch, in other parts of Colorado and in New Mexico.

MESOZOIC ERA.

Towards the close of the Carboniferous age a change of sea-level occurred, and it is possible that then nearly the whole of San Juan County, with much of the adjoining territory, was raised above the ocean, so as to form a new shore-line not far from the present western boundary. This seems more probable from the fact that important formations which succeed the Carboniferous elsewhere, have not been discovered over this area, and there has been observed an evident want of coincidence between the red sandstones of the Carboniferous and the next succeeding formation.

"Parachronous"* beds, of later date than the Carboniferous, represent in Europe two well-defined ages, which are less clearly sepa-

* Beds which were simultaneously deposited are said to be "*synchronous*," or of the same *actual* age. "*Parachronous*" beds are those of the same *relative* age in different regions. This latter term was proposed by the writer in 1873, in Geol. Rept. N. W. Wyoming Expedition.

rated in Western North America. Our representatives of the Triassic and Jurassic ages are commonly grouped together under the comprehensive title,

THE JURA-TRIAS AGE.

I am not aware of an exposure of these beds in our county, though it is impossible to say just what would be brought to light if the porphyry-cap were wholly removed. During the long epochs in which vast beds were forming over other sections, it would seem that our county was, for the most part, an elevated tract of dry land above a seething caldron of molten and semi-fused rock, struggling to escape, but not yet able to burst the bonds which confined it.

CRETACEOUS AGE.

Our county is also deficient in outcrops of the most modern marine beds existing in Southwestern Colorado, and the whole of the Rocky Mountain region, although well-defined beds of the Cretaceous formation are visible in the cañons of the principal streams not far beyond the county lines. The great thickness of the volcanic outflow over the greater portion of San Juan County completely obscures the substructure, as even the extensive erosion by the streams has not been sufficient to lay bare any of the underlying rocks, except in the few places where folds have been caused, or in patches never covered by the porphyries. I believe we must regard all the exposures of the Palæozoic rocks, where no strong folds occur, as patches uncovered by denudation of the overlying strata. It is instructive, however, to observe that the great events of the succeeding era have been foreshadowed by the elevation of the land, which probably continued throughout Mesozoic time, until it culminated in

THE CENOZOIC ERA.

The close of the Cretaceous age was marked by the emergence of the Rocky Mountain region from beneath the sea. The upheaval was gradual and long-continued. The ridges were formed in the trough of a great depressed fold, and in the north, in Dakota and Wyoming especially, as well as in Nebraska, the intervening hollows became the sites of vast brackish water lakes, which gradually became freshened by disconnection from the open sea. In these were deposited the now famous strata of

THE TERTIARY AGE.

The upheaval continued more or less gradually into this age, and throughout the whole of it. Over the northern area, it was somewhat abrupt in the later Tertiary, but much more steady in the earlier part. There seems to have been a very constant tension in the rocks of our district during the greater portion of the time. Finally, the resistance was wholly overcome, and the molten material flowed out through fissures in the axes of the greater folds. This movement was quite general over the Rocky Mountain region, but more extensive and of longer duration northward.

San Juan County is now largely covered by the igneous rocks of this age. Richthofen has divided the series, as it is exposed at its best, in sections more than one mile in thickness, along the Columbia River, into members based upon mineralogical characteristics, as below:

a. PROPYLYTE.
b. ANDESYTE.
c. TRACHYTE.
d. RHYOLYTE.
e. BASALT.

The above are given in the order of age, the *propylyte* being the oldest and the *basalt* the latest formed.

a. Propylyte.

We have here a prominent series of rocks which might be readily mistaken by a casual observer for some of the transition members of the trachorheites genus, though these will not deceive the practised lithologist. They are not hornblendic, but resemble more closely the phonolytic lavas of the present, being quite typical representatives of the acidic group of volcanics.

The best exposures of propylyte are generally found in localities near the limit of volcanic overflow, upon the eastern or western edge of the igneous belt. One who has studied these deposits extensively in the north will always be able to recognize at a distance the lowest member of the series by the general character of the formation. It is there almost invariably associated with thick beds of breccia, of which it forms a component. These breccias, when subjected to the action of water and the air, become worn into various fantastic forms, often closely simulating familiar objects, such as castles, pinnacles, fortresses, etc. In our county there are no marked exposures of the

breccia, and I am inclined to think that it was not extensively deposited here; otherwise we should expect to discover it along the outer edge of the area of volcanic rocks, which is not the case, as far as I have been able to learn, within this county. Outside the limits of the county eastward, along the valley of Pinos Creek, between Del Norte and Summitville, and along the line of the Denver and Rio Grande Railroad, in the Toltec Gorge, this peculiar formation may be seen to good advantage. Where the ancient volcanic activity has been very great and the deposition of the propylyte very extensive, there may be considerable differences in composition, beginning with the breccia, cemented by a dark greenish paste (often mistaken by prospectors for a copper ore), and ending with a light or dark-colored porphyry, scarcely to be distinguished from the overlying andesyte.

The typical propylyte is a hornblendic variety of trachyte-porphyry, or, using Dr. Endlich's phraseology, one of the series of trachorheites. Its special characteristics need not be discussed here, for it is rather strangely absent from our district, and there is good reason to believe that none of it has ever been deposited in this section of the State.

b. *Andesyte.*

Along the Columbia River, and over a very large portion of the volcanic area of Montana, Idaho, Nevada, and Wyoming, the propylyte is covered by a later lava, which cuts through and overflows the earlier greenish beds. It varies in color from light to dark, almost from white to black. This member of the volcanic group is also absent from our district.

c. *Trachyte.*

Almost the whole area of San Juan County may be said to be covered with trachyte-porphyry. It is necessary to use this broad term to include all the varieties, and yet there are really no exposures in Southern Colorado of any but No. 4, or the youngest of the series, as described by Dr. Endlich. We find abundant evidence that extensive folding of the strata occurred at the close of the Carboniferous age, and also that a long period elapsed afterward before any outflow of volcanic material took place. In this interval, comprising the whole of the Mesozoic era, extensive erosion of the land was caused by the action of running water. Afterward, Dr. Endlich clearly shows, in the early part of the Tertiary age, perhaps, a vast fissure was produced in the neighborhood of the Uncompahgre Moun-

tains, north of San Juan County. Through this came a flow of lava, which produced by its cooling the trachorheites (propylyte and andesyte) which covered a wide area outside of our county. Taking all the facts, we have proof that our section, while it did not wholly yield to the pressure, was yet rising constantly from the close of the Carboniferous until this period (Eocene?). But our area was evidently so lofty that the trachorheitic flow did not cover it. The elevation continuing on into the middle tertiary (Miocene), a new fissure was produced not far from the first, through which came the trachytic lavas.

I think I have collected data enough to explain why, in this county, we have only one division of the trachytes, while other portions of the State exhibit three other well-defined and earlier sets of flows. Aside from the altitude of the region, which still prevented the Uncompahgre flow from covering it, there are strong evidences that even the No. 4 of Dr. Endlich would not now extend over its present *locus*, had not the excessive tension at last caused the lavas to burst out in a new place farther south. As will be more clearly pointed out in the discussion of the vein-formation of the district, I am forced to the conclusion that the trachyte No. 4 represents, in its layers, the successive outflows from a vast crater, occupying the greater part of San Juan County north of Silverton. This view is confirmed by the present aspect of the drainage, as well as by the constantly varying dip of the trachyte layers in directions concentric to Red Mountain, with local modifications referable to buried folds in the subjacent strata, that would otherwise be difficult or impossible to trace.

The lower, or earlier, layers of trachyte No. 4 are light-colored, as a rule, but weather red, brown, and yellow by oxidation of minute pyrite crystals impregnating the mass. Anvil Mountain, Red Peak, and portions of Crown and Eureka mountains, show this character very decidedly, but in many other places the "red stratum" is overlaid and obscured by the upper layers, which are darker colored in their weathering, and, withal, more durable. In the higher members we have another, the mottled-green trachyte, varying more or less in character, with occasional beds of lighter color. All of these are porphyritic (*i. e.*, they inclose crystals of feldspar). Near the top of the series the normal trachyte of European geologists, a purplish variety, is sometimes met. Dr. Endlich mentions the occurrence of a rock near Bear Creek Pass, which I have observed in various parts

of the county, always in beds above the middle of the trachyte series. It consists of a compact base, studded with small crystals of epidote. The same, or later layers, also often show the epidote filling minute crevices like veins. In Niagara Gulch, at Eureka, these features are quite common, and I have also noticed crystals and thin seams of magnetite associated with this rock at the Cuba mine in the same locality. In the Boomerang mine, which traverses some of the highest beds of the series, the rock has occasionally the appearance of the normal trachytes, but the inclosed feldspar is anorthite, in consequence of which it weathers soft and rapidly. This feature is especially prominent in the enclosing rock of the North Star vein on Sultan Mountain, sufficient lime being produced by the weathering of the country rock to give the water a milky appearance.

In the rock of the Diana Tunnel, also upon Sultan Mountain, there is a peculiar admixture of rounded pink quartz pebbles, sparsely scattered. This I have not observed at any other point and at present I am inclined to regard the layer in which it occurs (not the latest, but of more recent date than those previously noted) as one of a series of local crater outflows, which have included portions of some of the neighboring sedimentary strata.

d. Rhyolyte, and e. Basalt.

Rhyolytic exposures are few and of little importance, occuring chiefly at the summits of the highest peaks nearest the source of the outflow. These rocks shade gradually into the trachytes below, and they are nowhere overlaid by the basalt, unless it be in a very few isolated cases. The basalt formation beyond the county lines northward and southward was probably poured out from fissures or craters late in the Tertiary age.

Post-Tertiary Age.

There is no sudden transition from the Tertiary to the succeeding age. It is highly probable that the volcanic activity had practically ceased at the close of the former, but the minor phenomena undoubtedly manifested themselves to a later date.

a. Hot-Spring Deposits.

The existing hot springs at Wagon Wheel Gap, Pagosa Springs, and other points in this State and in New Mexico, Wyoming, Montana, etc., are directly connected in most cases with the volcanic area;

and, in addition, there are countless other tracts where the deposits from ancient thermal springs, now extinct, may be studied to good advantage. The best preserved relics of this character near our district are visible at the northern end of Lake San Cristobal, on Slumgullion Creek (Hinsdale County), and just across the line of San Juan County, on the Silverton and Ophir road, about two miles above Ophir. Some remnants also occur along Bear Creek, a short distance above its junction with Mineral Creek, and some of the deposits in Cement Creek and near Silverton and Eureka in the Animas Valley, are less certainly traceable to the same origin. So far as I have been able to study these accumulations, they appear to lie directly in the track of trachyte No. 4, and I am very strongly inclined to the opinion that very few of the variegated and highly-colored outcrops of the "red stratum," previously referred to, have been due to other agencies. The explanation given by Dr. Endlich, that these colors are due to oxidation of pyrites is, no doubt, correct, but I have frequently observed the same trachytic layer, well exposed to ordinary atmospheric agencies, without more than a browning of the rock. From my own studies, in 1873,* of the most remarkable hot spring district in the world (Yellowstone National Park), I recognize clearly the causes which have produced these features here.

The action of mere atmospheric agencies, I am fully satisfied, has not been sufficient to cause decomposition of pyrites to any considerable depth, whereas, the variegated tract, previously referred to, is discolored far beneath the surface. Moreover, the same stratum in different portions of nearly identical mineralogical composition, and similarly exposed, is frequently tinted in all shades from light buff or creamy yellow to the most brilliant crimson and scarlet. I have also noticed here the same variations in texture that are to be discerned in the deposits from the active thermal springs of the Yellowstone Park. Besides these interesting features, I have often met with patches of iron ore and sulphurous earths in the valleys of Cement and Mineral creeks, near the head of Howard's Fork of the San Miguel River, and elsewhere (*but always along the course of the colored belt, and never in other sections where trachyte No. 4 is equally exposed to ordinary "weathering" influences*), and in almost every case of this nature, there is some well-marked indication of hot-

* See Geological Report, by Theodore B. Comstock, in Reconnaissance of N. W. Wyoming, including Yellowstone National Park, 1873. Captain W. A. Jones. Special edition from office of the Chief of Engineers, 1875.

spring action, such as a well-defined rim, a small lake or pool of great depth, or a mound of the tinted earth.

The exposure of this belt of extinct hot springs follows a course through the county, which is approximately the central line of the crater to which I have before referred. It is especially prominent upon Red Mountain and Anvil Mountain, and at points in the Animas Valley, between Eureka and Howardsville, and opposite the mouth of Boulder Gulch.

My own observations show that few, if any, metalliferous veins occur directly in the belt itself (except possibly in a limited area on Red Mountain), although some of the best in the county are not far from it.

Some of the areas are still dotted with cold pools, marking the positions of the former thermal springs, but such are rare in San Juan County. La Plata County, between Silverton and Durango, has some important existing hot springs.

The deposits from these ancient springs consist of ferruginous and sulphurous earths, intermingled with siliceous material, being just the substances one would expect to find separated by such agencies from the ingredients of trachyte No. 4. These products resemble closely the deposits now forming at those hot springs of the Yellowstone National Park, which emerge from the later trachytic layers. Further study will, no doubt, lead to some interesting developments.

Excavations made along the lower valley of Mineral Creek, near Silverton, at the Comstock Sampling Works, reveal a deposit of ferruginous cemented gravel, apparently of hot-spring origin, which is now covered by from 3 to 100 feet of alluvial gravel. Above these works there is a fine exposure of the colored belt, and a large bed of iron ore, known as the Iron Placer, lies in the course of the creek, giving a very strong mineral taste to the water.

b. Glacial Phenomena.

1. *Glaciers.*—It is highly probable that important ice-masses covered the greater portion of San Juan County during much of the Post-Tertiary age. In the quartzite group, just outside of the county, near Weenimuche Pass, the characteristic striæ and glacial scorings and polishings may readily be detected, but it is likely that the snow-cap in our section was nearly stationary during most of the earlier, or glacial, period; for there could hardly have been any point low enough for it to reach a temperature below the freezing-point. Thus, the very agency which gullied and eroded the quartzite area south-

ward actually served as a protection to the denudation of the district we are discussing. Nothwithstanding this assumption, we find large quantities of "drift" in this county, some of which I have reason to know is certainly of glacial origin in its present condition. Every winter, in certain localities, as notably in the Animas Cañon, a little south of Grouse Gulch, very fine examples of miniature glaciers may be seen, with all the peculiarities of the largest, but upon a reduced scale. The crevasses, "glacier tables," moraines, etc., may be as closely studied in these models, as at any point upon the famous Alpine glaciers. There can be no doubt whatever, that these periodically recurring ice-movements have aided very materially in producing the existing topography, though it is quite difficult to estimate their proportionate effect, on account of the comparatively important results of other agencies simultaneously operating. At least a portion of the cutting of the cañons must have been done by glaciers. Some small examples of "roches moutonnées" may also be seen in side gulches along the Animas River.

2. *Avalanches.*—Relatively of even greater importance in this section have been, no doubt, the effects produced by sudden snow-slides. Immense deposits have accumulated in the valleys by this means, often damming up streams and changing their courses in many instances. Since my own arrival, in 1879, some important changes in minor topography have been caused by this means, as well as by destructive land-slides.

c. *Diluvium and Alluvium.*

The floods which occurred in the next period (Champlain) by the melting of the great snowcap of the Glacial period, caused vast amounts of the various forms of drift material to be rearranged by the water. All the valleys are consequently filled to unknown depths with rock débris, composed of gravel and boulders. So far as San Juan County is concerned, there has evidently been no serious reversal of drainage, as in many other regions, since the Glacial period, though there is some reason for the supposition that the Animas River originally passed out of Baker's Park by way of Mineral, Bear, and Lime creeks, and that the Grand Cañon has mostly been eroded by water since the Champlain period. Prior to the volcanic eruptions, it seems quite probable that the drainage was principally eastward and southward, but the courses of the streams at that epoch are now wholly obliterated, the valleys having been silted up to great depths.

The amount of the diluvial deposits in the valley of the Animas between the northern line of the county and Silverton is wonderful to behold, and the alluvial deposits made by the river in assorting and transporting the material southward are beautifully graded. It is very interesting to see recorded here all the phenomena of the three great periods of the Post-Tertiary age in the same order as they are exhibited elsewhere in the United States, and I cannot resist the expression of the conviction that future geologists will give to the Glacial, Champlain, and Terrace divisions all the dignity of separate ages in their classifications.

d. Terraces, etc.

Notwithstanding the great changes that have been wrought in the contours of the alluvial tracts by numerous avalanches of snow and earth since the Diluvial period, there still remain many excellent examples of terraces formed in the last period of the Post-Tertiary.

The elevation of the land after the floods of the Champlain period was as real here as in other regions, and the same causes have here effected a cutting down of the river-bottoms, step by step, until the former "flood-plain" has been eroded to the depth of several hundred feet in some places. The highest terraces are much above the next lower series, and each successive set is nearer the level of the one next below. At the close of the Champlain period, Baker's Park was covered by a large lake extending up Mineral Creek several miles, with an arm protruding into Cement Creek a mile or more, another down the Animas Cañon more than a mile, with its northern end above Howardsville, and further prolongations into Arrastre and Cunningham gulches. The depth of this lake was fully three hundred feet to five hundred feet. At the date of the next terrace its level had fallen at least fifty feet, and, at the second break in the elevation of the land, several smaller lakes were formed over the area. The complete drainage of the Silverton Lake and the connection of Cement and Mineral creeks directly with the Animas River have only been effected within a comparatively recent period, as these tributaries have only two low terraces along this portion of their course through the town. The cañon of the Animas above Eureka for nearly a mile, the gorge between Howardsville and Boulder Gulch, and the Grand Cañon for two miles below Silverton, as well as the channels of nearly all the side creeks between Eureka and Silverton have been cut through solid rock to the depth of nearly three hundred feet since the close of the Champlain period. Howardsville is built upon the

second terrace from the top, and Silverton lies upon the second from the last. Cement Creek joined the Animas while yet the mouth of Mineral Creek communicated with a fair-sized lake, into which the upper Animas flowed. Some of the terraces at Silverton are as regular as any I have ever seen.

PSYCHOZOIC ERA.

Coming now to the historical age, we have only to add that most of the surface agencies which have been at work in the past are still acting to modify the topography of the county. Snowslides in the winter and landslides in the summer are, perhaps, the principal destructive agents; but from such observations as I have been able to make in the past few years, it is my own opinion that the protective and reproductive action of vegetation and human works are already exerting a most powerful influence in a contrary direction. Snowslides are frequently inoperative for several seasons in succession, and nature and art have combined, in many places, to prevent their occurrence. Landslides, which only take place in particular localities, seldom happen in the same place oftener than once in a long series of years, and then but rarely, except in very rainy seasons. The clearing away of the timber upon slopes has had an unfavorable effect in some cases, but no very serious results have followed as yet.

The action of frost, running water, the wind, and chemical action in weathering rocks are all important and noticeable, but we cannot now stop to consider these matters. A subject of greater interest just now is

THE MINERAL VEINS OF SAN JUAN COUNTY.

It will be most convenient to study the distribution of these before discussing their geological relations.

The great bulk of our veins have their surface exposures in trachyte No. 4, and are consequently of later date than the Cretaceous age, in so far as their upper portions are concerned. I am not aware that any of the lodes which traverse the trachyte have been followed by development, as yet, into the underlying formations; but there is plenty of evidence that the veins are deep-seated in their origin, or, at least, that they do extend to untold depths. The granites, schists, and quartzites, as well as the overlying sedimentary limestones and sandstones, all contain excellent veins, and some of the claims in Cunningham Gulch and upon Sultan Mountain can be traced down-

ward through the trachyte into the lower beds, while the existence of chlorite in the Peerless and other mines in Arrastre Gulch points to the close connection of these veins with the metamorphic series, which is not there exposed.

The fissures in the metamorphic rocks are usually large and well-filled with mineral, but they are equalled often in size and quality, as well as quantity of mineral, by many which traverse the overlying porphyry. It might be thought that the fissures in the volcanic rock have been filled by material supplied by previously formed veins in the sub-strata. Some color is given to this idea by the fact that many of the lodes in the trachyte seem to converge in depth, as if they would unite into one below. I must confess that these facts, taken alone, go far to support such a theory, and at one time I was nearly convinced of its applicability. The occurrence of some of our best gold and silver ores in districts where the porphyry cap is thinnest, and where it is known that the veins extend down into the metamorphics, also renders this view more plausible. But, on the other hand, a large number of the richest and most extensive fissure-deposits are to be found in the higher layers of trachyte No. 4, at points where there is no reason to suspect the existence of lower rocks within a vertical distance of at least 1500 to 1800 feet or more.

The great mass of the evidence which I have collected from all points, when carefully weighed and sifted, leads to the conclusion that the metalliferous veins of San Juan County are principally of Post-Tertiary date, being about simultaneous in origin with the hot springs. In the quartzite group there are many veins and seams of quartz which were probably formed before the deposition of the trachyte, but all the veins which bear metallic ores are of later date, without question. The courses of the lodes are quite numerous, and bear no definite relations to the trend of the principal folds in the Palæozoic rocks, as might be expected if the present surface-veins were formed directly from pre-existing ones. But, aside from this, I am prepared to show that all our important veins, of whatever trend, can be traced to some prominent points, from which they spread out in a radiating manner. On this account we have in the county examples of almost every conceivable trend, and the veins of the same district do not run exactly parallel, except in rare cases. The nearer one approaches the peak or other focal point the more noticeable become the differences in direction of the neighboring lodes. The centres of radiation are not to be determined exactly by reference to the present topography; that is to say, erosion has so modified the outlines that some

of the highest and most prominent landmarks to-day are not the geological vein centres. A study of trends shows, for instance, that Hurricane Peak, Sultan Mountain, and Niagara Mountain are not the focal points of any systems of fissures. A prominent peak on Engineer Mountain, Handie's Peak (Hinsdale County), Kendall Mountain, and some others are among the principal foci, Red Peak being the main centre towards which the primary veins converge. The cause of this distribution of the fissures is easily understood by reference to our previous discussion of the *locus* of the trachytic eruptions. The dip of the successive layers of trachyte No. 4 is such as to indicate the position of the main outbreak in the neighborhood of Red Peak, but cross-bedding of the later outflows locates the minor eruptions at the focal points of the secondary fissures.

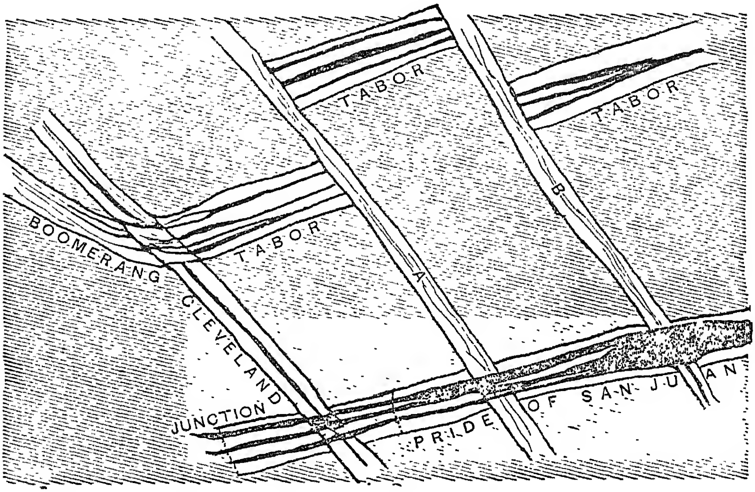
An unbroken line of claims upon a single bold vein, can be traced from near Sherman, in Hinsdale County, up along the course of Cottonwood Creek, over the divide along the head of Niagara Gulch, crossing the Animas River, just above Eureka, thence up Eureka Creek to the Forks, and intersecting the valley of Cement Creek a little below Gladstone, piercing the centre of the Red Mountain district beyond, the whole belt including a distance of not less than fifteen miles. Upon this immense vein are the Confidence, Cashier, Roving Ranger, Centennial, Cuba, American, McAlpine, McKinnie, Alta, Money, Musk, and numerous other locations, all showing large and well-defined ore-bodies. It is a significant fact that the trend of this fissure is almost exactly parallel with the known course of some of the exposed Palæozoic folds, and there is every reason to believe that it marks the line of a buried ridge of the metamorphic rocks, which will be eventually reached in the deeper workings of the mines upon the vein. Indications of such a fold are visible at points along the course of the vein, in the form of local outcrops of limestone, granyte, etc.

The effects produced by the later veins in crossing those of the earlier epoch are quite varied, and yet dislocations from this cause are comparatively rare, as far as one can judge from surface indications.

In the accompanying cut I have illustrated a peculiar instance, showing clearly the influence of the primary veins in these results. The three secondary fissures, though effecting important changes in texture and structure at their intersections with the Tabor vein, have all crossed the Pride of San Juan in such a manner as to leave but slight traces of their course at the point of traverse.

If the views here advanced be correct we may expect to find the

cross-veins of the later epoch, as a rule, smaller and more superficial than those of the primary series. My own observations convince me that this is the case in our county, but it requires the exercise of much patient field work and very careful examination to detect the difference between these minor secondaries (or crater-fissures) and another set of cross-veins of much importance, which we frequently meet in this district. These are, I am convinced, primary veins of about the same age as the main fissures, which they closely resemble in structure and mineral components. In the cut, the Cleveland



Effects produced by secondary fissures upon two parallel veins in Niagara Gulch, near Eureka.

vein I regard as a *cross-primary*, while A and B are undoubtedly true *secondaries*. The former carries distinct ore-streaks, similar in character to the main veins which it crosses, while both the latter are practically barren, except at their junction with the primaries.

The foregoing conclusions are based upon a wide array of facts, and it may justly be claimed that these include a considerable amount of evidence bearing directly upon the course and composition of the veins in depth. At the same time our knowledge of this character is chiefly derived from natural sections, which are open to serious objections. It will not, therefore, be possible to arrive at a full understanding of our vein-structure until more extensive developments have been made in the mines. Thus I am obliged to give light attention to the discussion of the distribution of minerals, a

subject upon which I have collected many facts that may be capable of classification at a later date.

The ores of San Juan County are but seldom true silver minerals, although native silver in wires and strings in quartz is not a decided rarity. Dry ores are abundant, and smelting varieties even more so. Galena, pyrite, chalcopyrite, bismuth compounds, and tetrahedrite (largely freibergite) are the predominating mineral species. Both varieties of ruby silver are often encountered in smaller quantity, and compounds of antimony and tellurium are more or less frequent. Rarer ingredients of our veins are molybdenite, native silver, nickel compounds, silver sulphurets, and the copper carbonates and sulphates. Sphalerite is not often injuriously abundant, but it occurs in many veins, associated with high-grade silver-bearing ores. Recently some interesting and important discoveries of copper oxides have been made also.

One of the most commonly valuable components of these ores is *tetrahedrite,* though there are some districts where it is almost invariably low in silver. In Cunningham and Arrastre gulches, in the Animas Cañon, and at other points not far removed from the metamorphics, this mineral is peculiarly rich and abundant. For some distance around Eureka, and in Poughkeepsie Gulch, bismuthinite (*alaskaite* of Koenig) seems to replace tetrahedrite, and the copper occurs profusely in other minerals less rich in silver. I have met no large deposits of bismuthinite which do not carry at least 75 ounces and upwards of silver to the ton. Gold, I think, is also more constant in presence of this mineral, though very rarely found in the mineral itself. In the northern portion of the county much of the tetrahedrite carries very little silver. This difference in quality is not due, I believe, to the more superficial exposures of the veins northward, but rather to influences connected with the filling of the fissures of which our knowledge is at present incomplete. The quantity of silver and gold in these northern veins is not less than elsewhere, but it seems to have become mingled with a different class of minerals. While I think I am now on the road to an explanation of this matter, my confidence is not yet sufficiently strong to advance a theory. It is, however, worthy of remark here, that we may roughly divide the numerous primary vein-courses into three sets of trends, bearing towards Red Peak, viz.:

1. The northwest trend, comprising the principal veins south of Howardsville (excluding a portion of the county south of Silverton). These are pre-eminently the tetrahedrite (gray copper) lodes.

2. The west trend, including most of the primary veins between Maggie and Picayune gulches and Red Peak. These constitute the *bismuth* series of lodes.

3. The southwest trend, extending over the area north of the preceding to an undetermined line beyond the limits of San Juan County. These veins belong chiefly to the *telluride* series, the precious metals occurring usually in ores of tellurium, antimony, etc., or as sulphides.

The distribution of galena, pyrite, chalcopyrite, arsenical compounds, etc., is not restricted, these minerals occurring alike abundantly in all three districts. Nickel compounds, molybdenite, and copper salts are more characteristic of the bismuth series, as far as yet reported.

A fourth district, comprising the southern portion of the county, has not been as thoroughly investigated, but the facts gathered from that section indicate characteristics of a different type, due to more intimate relations with the metamorphic and sedimentary rocks. This area passes from a non-mineral tract on the east, across the county line, into a "free gold" area upon the west, in Ouray County. Over this tract oxides and carbonates are more common and the galenas are richer in silver. The Red Mountain mining district is here included.

The ordinary gangue of our veins is quartz, with other minerals occurring occasionally in the following order of preponderance: calcite, barite, hematite, fluorite.

So far as I have been able to study the subject of the relative age of minerals in this district, I am inclined to the opinion that the order, beginning with the earliest formed, is pyrite chalcopyrite, sphalerite, galena. In banded veins, this arrangement is often found, as in the North Star mine, on Sultan Mountain, and in many others which I have observed closely. At any rate, it is rather safe to set down pyrite as one of the oldest, and galena as one of the most recent components of the veins of the region. Without enlarging upon this subject here, I desire to point out to students of vein phenomena, the close bearing of such facts upon the probable formation of our local veins by aqueous infiltration by means of thermal springs.

The large deposits which are now causing the great rush to the Red Mountain district, are, in my opinion, the representatives of the latest epoch of vein growth, and they must be regarded as occupying caverns left by extensive hot-springs. On this account they

will, I judge, be found to be quite irregular in position and dimensions, though it is probable that they will hold out in depth, much like the more common and regular fissures, with diminished cross-sections.

The distribution of gold in San Juan County is not restricted, this metal being found very commonly in all sections, though but rarely in a free condition, and not often in sufficient quantity to make it profitable (at least at present) to work the veins for this alone. In many veins gold seems to be very uniformly distributed, small specimens of the quartz and other minerals separately, and even adjacent portions of the country-rock, giving, by assay, the same amount per ton as sample assays of lots of from ten to fifty tons. Ordinarily, the yield is from two-tenths of an ounce to six-tenths of an ounce per ton; but some veins carry as much as two ounces to two and a-half ounces per ton.

In conclusion, I may record the conviction that future studies in this little county will do more to unravel the history of vein-formation than similar investigations in any equivalent area in the world.

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*THE TREATMENT OF GOLD-BEARING ARSENICAL ORES AT DELORO, ONTARIO, CANADA.**

BY RICHARD P. ROTHWELL, NEW YORK.

THE ores treated by the Canada Consolidated Gold Mining Company at Deloro, Ontario, have been described in a paper read before the Institute in 1881.† They are gold-bearing arsenical sulphurets of iron (mispickel), carrying the theoretical proportions of 42 per cent. of arsenic, 20 per cent. of sulphur, and the remainder iron. The gangue is quartz, calc spar, and some talcose, slaty rock, evidently resulting from the decomposition of the wall-rock, which on each side of the veins is syenitic granite.

The treatment of the ore consists of:

1. Crushing.
2. Concentrating.

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* This paper was announced, and the general facts embodied in it were given at the Colorado meeting of the Institute in September, 1882; but the paper, as now printed, contains also the results obtained at Deloro during October and November, 1882.

† *Transactions*, vol. ix., p. 409.

3. Roasting.
4. Condensing and collecting the arsenic fumes.
5. Chlorination of roasted concentrates.
6. Precipitation and melting of the gold.

1. Crushing. The ore as it comes from the mines is dumped over grate bars at the top of the mill building; what is too coarse to go into the rock-breaker is broken by hand, and all then goes through the No. 1 rock-breaker, which breaks it to a maximum size of 1¾″; then over fixed grate bars, which take out all pieces less than ½″ (12 mm.) in size. The coarse then goes through two small rock-breakers, which crush it to a maximum size of about ¾″ (20 mm.).

2. Concentrating. The peculiarity of the Deloro ore is, that the gold is contained for the most part in the mispickel (which carries, when closely concentrated, nearly $100 per ton as an average); and this mispickel is much more friable than the associated quartz and calc spar, which contain but small quantities of gold. The consequence is that, when the rock as it comes from the mine is coarsely crushed, we find the fine is composed, for the most part, of mispickel, and the coarse is quartz with a little mispickel. Taking advantage of this peculiarity of the ore the mill was constructed so that the ore from the second crushers and the fine from the first crushers would go into the No. 1 revolving screen 20′ long by 5′ diameter, where it would be sized into *fine* (*i. e.*, passing through a mesh of less than ¼,″ (8 mm.), and the remainder into two sizes, which would go to coarse jigs (Bradford's). These jigs are intended to separate into a rich and a poor product, the rich, after drying, joining the fine from the No. 1 screen, and going to the rich rolls to be crushed to the roasting size, and the poor going to the poor rolls and jigs. The object sought to be attained by this arrangement was the partial concentration of the ore without the usual loss in concentration; but as the roasting and chlorinating capacity of the Deloro works is yet far inferior to the mill capacity, it has been deemed wiser for the present to crush in the poor rolls all the ore as it comes from the second rock-breakers, and concentrate it in the jigs. The crushing is done dry in Cornish rolls 36″ diameter, 15″ face, steel shells on double cone centres. These rolls will be described in another paper.

The ore, after passing through the rolls, is elevated to the two No. 2 dry screens, which have a length of 8′ by 4′ diameter. In these the ore is sized. All passing through a 1½ mm. mesh is carried with a stream of water into the No. 3 screens. The size passing over 1½ mm., and, which comes out of the end of the No.

2 screens, drops back into the rolls and goes through again. The fine ore is sized in the usual manner, except that the screens are much larger than usual; for the limiting capacity of such works is always found in the screens. Each set of rolls has a capacity of fully five or six tons an hour in grinding hard quartz and mispickel down from say 20 mm. to a maximum of $1\frac{1}{2}$ mm.

The crushing (and consequently the screening in the No. 1 and No. 2 screens) is dry. The sized ore is concentrated in ordinary Hartz jigs, discharging through the bottom, and the slimes in spitzkasten and on Rittinger tables. I would prefer other concentrators of greater capacity to these tables, though they do very fair work.

3. ROASTING. The concentrates are taken from the jig room in a tram car, which, going up an inclined plane, delivers them directly into a hopper over the drying furnace. This is an inclined revolving cylinder 20′ long, 36″ diameter at small end, and 48″ at large; and it has a conical addition of 24″ in length at the small end, making the total length 22 feet. The fire passes through this cylinder, and the capacity has never been tested to anything like its limit; but, no doubt, it would dry two tons an hour if required. It is very economical in fuel.

As the dry ore drops out of this it is raised in a continuous manner by an elevator into the No. 1 roasting furnace. This is a revolving cylinder 30′ long, 60″ diameter outside, lined with $4\frac{1}{2}$ inches of firebrick, and with eight shelves running through nearly from end to end. These shelves are formed of key brick 9″ long, so that they stand $4\frac{1}{2}$″ out from the lining.

In this furnace the arsenic and the greater part of the sulphur are volatilized, and pass out through a long series of arsenic condensing chambers, and through a centrifugal (Guibal) fan 8′ diameter, 3′ face, used to make the draft to the stack. The ore runs from the first cylinder through a pipe directly into the second cylinder, 20′ long, by 48,″ with a $4\frac{1}{2}$″ lining and 6 shelves, where the roast is completed. The escaping gases pass to a stack, which also serves the drying furnace.

The air which feeds the No. 1 furnace is preheated by the escaping gases of the second cylinder, by passing through an air space between the two arches which form the top of the second roaster dust-chamber.

The two roasting cylinders are jacketed, first with an air space, and then with a covering of mineral wool, and paper over that. The whole arrangement of the roasting cylinders, their jacketing, and

the plan of utilizing the escaping gases to heat the feed air for the first cylinder are believed to be new, and are found very economical and efficient in practice.

The jacketing of the roasting cylinder will form the subject of another paper to be read at the next meeting of the Institute.

The ability to make a sweet roast (such as is required for chlorinating) in a single operation, in continuous revolving cylinders, has been questioned by some metallurgists. In proof of its feasibility I may say that, in the continuous arrangement above mentioned, we have roasted ten tons of concentrates in twenty-four hours, and to such perfection that, in the subsequent chlorination by the Mears process, we extracted from 93 to 98 per cent. of the gold, as will be seen by reference to the following table:

Roasted Ores.		Average Value Tailings.	Percentage Extracted.
Tons.	Average Value Per Ton.		
16¾	$20.14	$2.63	86.94
19½	32.59	2.88	91.24
47	55.58	2.67	96.28
49	24.11	1.41	94.54
142¼	$35.19	$1.95	94.50

4. Condensation and Collection of Arsenic.—It was also asserted by some metallurgists that the roasting of arsenical pyrites presents many difficulties; but, after a pretty full experience with these Deloro ores, I can affirm, on the contrary, that they roast with much greater facility, and in about two-thirds of the time necessary to roast simple sulphurets. They stand almost any amount of heat without fusing, and the arsenic, which forms 40 to 42 per cent. of the mispickel, volatilizing at a comparatively low temperature, seems to leave the mass porous, thus facilitating the oxidation of the sulphur. The arsenic condenses readily in the series of brick chambers between the furnace and the stack.

The use of a centrifugal suction fan through which the furnace gases are drawn, and the draft of the furnace thereby created, is also believed to be a novelty in metallurgy, which has here proved itself both practical and economical. It is clear that a blowing fan, which

would occasion the escape of arsenical fumes, could not be used in this case.

Many important lessons have been acquired by experience at these works in regard to the construction of condensing chambers and the condensation of arsenic fumes, and I shall probably make them the subject of a special paper at some future meeting of the Institute.

5. CHLORINATION OF THE ROASTED CONCENTRATES. — The roasted concentrates are chlorinated by the Mears process, in charges of one ton, in a revolving lead-lined iron cylinder. The chlorine is made from chloride of lime and sulphuric acid, from 40 to 50 pounds of the former and 50 to 60 of the latter being used to a ton of ore. The pressure in the cylinder rises to about 40 to 50 pounds per square inch, and falls to 25 or 30 when the roast has not been so perfectly made as is desirable. The operation lasts about two hours, though probably much less time than this will be found sufficient to completely chlorinate the gold when it is in fine particles.

The completeness with which the gold is extracted is shown in the above table, which represents the whole amount of roasted ore chlorinated at the Deloro works of which I have the headings and tailings assays. The ore and tailings were very carefully sampled, and each ton of tailings was assayed separately; sometimes the samples from three tons of ore were united in one assay, but the tailings were assayed ton by ton. The results were remarkably uniform; and, after some experience had been gained, and especially after the second roasting cylinder was added, and the roast made more perfectly, the percentage extracted increased. This was also the case as the ore was concentrated more closely. The first $16\frac{3}{4}$ tons chlorinated were of partially hand-picked ore, crushed before the concentrating machinery was ready. After making about twenty tons of concentrates a closer work was made, and the concentrates frequently ran \$70 to \$85 per ton. In such cases the percentage of the gold extracted reached 98 per cent.; and as the mean of forty-seven tons, containing on an average $\$55\frac{58}{100}$ per ton, the percentage extracted reached $96\frac{1}{4}$ per cent.

After that, the concentrating machinery having frozen up, unconcentrated ore had to be roasted; but, greater skill having been attained in the roasting, the chlorination extracted $94\frac{1}{2}$ per cent. These results are considered as highly satisfactory both in roasting and chlorinating, especially when it is considered that they represent the first $142\frac{1}{4}$ tons roasted and chlorinated in the works, and that with almost exclusively unskilled labor.

6. PRECIPITATION OF THE GOLD.—The lime contained in the ore was found to give rise to quite unexpected difficulties in precipitating the gold from the chloride solution. The usual precipitant, ferrous sulphate, was found to throw down a voluminous precipitate of (principally) calcium sulphate along with the gold. In order to avoid this we tried to get rid of the lime first by sulphuric acid. This was too tedious, and, after many annoying delays, the precipitation by charcoal was tried. The chloride liquor is allowed to filter slowly through a mass of charcoal broken to say $\frac{1}{16}''$ to $\frac{1}{2}''$ ($1\frac{1}{2}$ mm. to 12 mm). The barrels are kept full of solution by the filtrate being brought from the bottom of one barrel in a rubber tube which terminates a few inches below the top of the next barrel. The precipitation of the gold is practically complete.

It may interest chemists to know that, though the lime does not remain in the charcoal, yet the liquor undergoes such a chemical change by its contact with the charcoal that the lime is no longer precipitated by either ferrous sulphate or sulphuric acid, but is by oxalate of ammonia.

Several chemists, who have experimented with this Deloro chloride liquor, have considered that hydrogen sulphide, either in a saturated aqueous solution or as gas, or ferrous chloride would make convenient precipitants, either of these reagents precipitating the whole of the gold without the lime. My own preference is for one of these rather than for charcoal.

The collection, drying, and melting of the precipitated gold is accomplished in the usual manner. The burning of the charcoal has not yet been done here; but in North Carolina,* where the same process is in use, it is burned in an open iron pan, and, it is claimed, without loss of gold, and at a cost said to be less than six cents per ton.

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* See the *Journal of the Franklin Institute*, Philadelphia, April, 1883, for description of precipitation of gold chloride by charcoal.

*NOTES ON THE RELATIONS OF MANGANESE AND CARBON IN IRON AND STEEL.**

BY ALEXANDRE POURCEL, TERRENOIRE, LOIRE, FRANCE.

THE perusal of Mr. Willard P. Ward's "Notes on the Behavior of Manganese to Carbon," presented at the Washington meeting of the Institute in February, 1882,† has suggested further reflections on the same general topic, and has led to the preparation of the present paper.

The same observation that Mr. Ward has put on record in his "Notes" was also made by myself at about the same time (in August, 1875), and under almost the same conditions. From a blast-furnace that was *very hot*, as was the furnace mentioned by Mr. Ward, I obtained a pig-iron containing about fifteen per cent. of manganese, gray in color, and very tough. It could be pulverized, but could not be cut with the chisel. I analyzed this iron and found that it contained, as I had suspected, a large amount of silicon. From this fact I drew the conclusion that the silicon had deprived the manganese of its power of dissolving carbon, since the latter, instead of occurring in the pig in combination, appeared as graphitic carbon. I thus saw reproduced on a large scale, and demonstrated in a visible way, the property that Colonel Caron, a French scientist, had discovered in silicon,—the property of obstructing the process of hardening in steels by keeping the carbon in the graphitic condition.

An attentive study of the conditions under which the phenomenon observed by Mr. Ward takes place led me to go back to operations of synthesis, and to make as I wanted them pig-irons containing varying quantities of silicon, manganese, and carbon. An iron, thus prepared, was intended to serve me as a chemical reagent in the production of steels cast without blow-holes, such as my lamented friend, Mr. A. L. Holley, has introduced and made known to the United States. What I needed in order to make very soft steels, cast without blow-holes, was an iron which, when it was added to the bath of steel, introduced into the bath a sufficient amount of silicon and of

* Translated from the French.

† *Transactions*, vol. x, p. 268.

manganese, with the smallest possible proportion of carbon. Now, in analyzing an iron similar in character to that obtained by Mr. Ward, I found that the amount of combined carbon in the iron was almost nothing, and that the total carbon was between 3 and $3\frac{1}{2}$ per cent., instead of being from 5 to $5\frac{1}{2}$ per cent., as in ordinary spiegels containing 15 to 16 per cent. of manganese.

I then sought for a way of still further diminishing the carbon by increasing the silicon and manganese, and after a few trials I found that when the manganese and silicon are present in the ratio of their chemical equivalents, the carbon reaches a minimum. It is well understood that the higher the percentage of manganese and of silicon in the pig is raised, the lower the percentage of carbon will be; an almost complete elimination of carbon might, indeed, be obtained by means of silicon, but the law which determines that the percentage of carbon shall reach its minimum is fixed by the ratio Mn : Si. When the manganese increases, the carbon increases also. For example, I have produced a number of tons of iron with from 11 to 13.5 per cent. of silicon, and from 17 to 19 per cent. of manganese, and the percentage of carbon has been the least,—2 per cent.,—with 13.2 per cent. of silicon and 17 per cent. of manganese, that is to say, when the two substances are present in the ratio Mn : Si.*

What are the reactions that take place in the blast furnace when a pig-iron, or rather an alloy, of this kind is produced? Are the phenomena simultaneous or successive? My opinion is that they are successive, and that the carburet of manganese is the reagent that reduces the silica from which the silicon is derived. We can in fact repeat that laboratory experiment which consists in maintaining a quantity of ferromanganese in a molten condition for several hours in a thick crucible, such as is used in the melting of steel. According to the length of time, more or less, that the ferromanganese is kept in the molten state, we find the walls of the crucible to be more or less attacked; the metal incorporates with itself a notable quantity of silicon, and loses some of its manganese and carbon. In this experiment there can be no doubt that the carburet of manganese is the reagent by whose action the silicon is derived from the silica in the walls of the crucible.

The laws of thermochemistry that have been established by Berthelot's numerous fine experiments equally confirm the opinion, to which I some time ago gave utterance, that when silicon and manga-

* Mn = 27.5, Si = 21.

nese occur together in a pig-iron or in a steel, they are in a state of chemical combination, as a silicide of manganese, if the percentages of the two substances are in the ratio, at least, of Mn : Si. It may, indeed, be affirmed that silicon when neutralized by manganese, that is to say, when for each chemical equivalent of silicon there is present a little more than an equivalent of manganese, does not diminish in the least the hardening property of steels. When the amount of manganese increases, the hardening property increases, since the manganese possesses the property of dissolving carbon, that is to say, of keeping it in the combined state.

As to the opinion of Mr. Ward that manganese has no injurious effect on the wear of rails, I may say that I hold the same opinion, though for an entirely different reason from that given by Mr. Ward. The deterioration of rails from atmospheric causes, which may be likened to chemical action, is due especially to their physical condition rather than to the chemical composition of the ingot from which the rail was made. A porous ingot, full of blow-holes, will produce a rail, on which, after a few months of service, the surface exposed to wear will be covered with numberless little rays or streaks, which are just so many more points of attack for atmospheric agents. Such a rail if laid in a damp tunnel will very quickly become useless. Possibly it would be used up a little more rapidly if it contained a high percentage of manganese, but in no case would the presence of that element be a principal cause of the effect produced.

If two rails, made from two ingots perfectly sound and free from blow-holes, are compared with each other as regards mechanical wear, my opinion, based on experience, is that the rail whose hardness lies within the limits I am about to point out, will resist wear more effectually than the softer one. The maximum of rigidity, combining resistance to bending with great power of resisting shocks, has been reached in rails of the following composition:

Carbon, ...	0.50 to 0.45 per cent.
Manganese, ...	0.90 " 1.10 " "
Phosphorus, ...	0.08 " 0.10 " "
Sulphur, ...	0.05 " "
Silicon, ...	0.02 " "

These rails, made from perfectly sound ingots, and laid on one of the busiest portions of a great network of French railways, after *three years* of trial have not given occasion for a *single* rejection, and the wear observed has been insignificant. Of other rails made from ingots equally sound, and differing from the preceding only in

having a smaller amount—from 0.5 to 0.7 per cent.—of manganese, some, indeed, have always been rejected after the regular test of three years, but that which has been especially remarked is that there has always been a notable wear of the top of the rail.

It is also known to me that the rails which have best stood the rude tests of percussion and bending, demanded by the Russian railways, contain about 0.3 per cent. of carbon, and from 1.1 to 1.2 per cent. of manganese. The manganese, without sensibly diminishing the elongation of the steel, increases its tenacity and rigidity, as well as its power of resisting shocks. It gives to the steel this grand quality of *hardness* without *brittleness.*

In the month of August, 1881, I had at my disposition quite a large number of old steel rails, made at different steel-works in Germany, and taken from the railways of Alsace-Lorraine. These rails had been worn out quite rapidly; they were all in very bad condition. The oldest of them bore the date 1874, and the mark "Bochum;" the most recent came from the steel-works, "G. H. Hütte," and were dated 1879! These rails in their chemical composition corresponded for the most part with the formula of Dr. Dudley,—those, at least, which did not have any excess of phosphorus or of silicon,—but their resistance to wear has not confirmed Dr. Dudley's opinion.

I have also been able to submit to the test of a blow a rail from the Phœnix steel-works, one from the Osnabrück steel-works, and a third made by Hoesch. The Phœnix rail showed the greatest power of resistance, but the metal is soft, it changes its form considerably, and lacks in rigidity. The Hoesch rail changes in form still more, and, besides, it is brittle. It broke under the shock of a weight of 300 kilograms falling through 3½ meters, the anvil weighing 12 tons (tonnes). The Phœnix rail withstood the shock of the same weight falling through 4½ meters. The Osnabrück rail, like that of Hoesch, is brittle, but it changes its form less easily.

In conclusion, like Dr. Dudley, I am of the opinion that elements like phosphorus, silicon, and sulphur, must be reduced to an absolute minimum in a good rail. I should insist especially on the phosphorus and the silicon, and less on the sulphur, but I do not put manganese in the category of ingredients that are injurious, either to the rolling or to the use of the rail. I should give the preference to a metal containing manganese to the amount of 1 per cent., as I have indicated above, a metal which is excellent for rolling and gives a rail of superior wearing qualities.

Table Showing Partial Composition of Different Rails.

Description of Rail.	Mn.	C.	Si.	S.	P.
Phœnix, ...	0.373	0.490	0.093	0.034	0.102
Krupp, ...	0.373	0.323	0.139	0.036	0.146
Bochum, ...	0.240	0.200	0.116	0.026	0.067
Union Dortmund, ...	0.240	0.284	0.046	0.039	0.239
G. H. Hütte, ...	0 480	0.382	0.139	0.039	0.080
Osnabrück, ...	0.586	0.170	0.466	0.045	0.174
Hoesch, ...	0.453	0.330	0.291	0.038	0.119

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*THE IRON ORES OF THE MIDDLE JAMES RIVER.**

BY DR. PERSIFOR FRAZER, PHILADELPHIA.

At a time when all those interested in the iron trade are carefully scanning the horizon for new sources of the raw material, a few words concerning a field, which though not new, has not been hitherto fruitful of statistical information, may be deemed appropriate at this meeting.

The district alluded to is the belt of the Middle James River, or in other words, that portion of the ferriferous belts of Virginia lying between Josua Falls and the little settlement of Norwood, in the counties of Amherst and Nelson, and on the left bank of the James River. This region shows unmistakable signs of developing a very considerable market for iron ores and for iron in the future, as well as a tempting appearance of possible productiveness in the former.

It is extremely hazardous to deal in generalizations as to the productiveness or non-productiveness of these measures without a more thorough development than has yet been attained. It is true that they probably constitute an horizon whence comes a part of the marvellous mineral wealth of the northern peninsula of Michigan. But

* The following paper, read at the Virginia meeting of the Institute (1881), has been amplified since that date by the receipt of fuller data, as well as corrected in accordance with the information contained in a note from Mr. Stockton.—P. F.

this, of itself, is not conclusive as to the true value or persistence of the iron-ore belts.

For example, the broad belt of rocks which extends from Northern New Jersey to North Carolina, and known as the Triasso-Jurassic or Mesozoic series, is characterized generally throughout the world by numerous features, among which is the existence within it of coal. But whereas this coal in the Midlothian collieries in Virginia and elsewhere exhibits large and profitable beds, which pay richly for working, no seam thicker than a couple of inches has ever been found in Pennsylvania to extend far enough among the strata to pay the costs of the simplest methods of extraction.

So that it does not always follow that the mineral contents of the same rocks, formed, so far as the geologist can tell, under the same conditions, are equally valuable (nor indeed that they must be commercially valuable at all), even though in two given localities the formation may be the same.

Whether this be the case with the James River and Lake Superior ores can best be judged after what remains has been read. The main point of inquiry into the subject may be thus stated:

What are the grounds for expecting paying deposits in these rocks?

The rocks through which the James River runs from Lynchburg to Norwood are those belonging to the Huronian system, or the second of the grander divisions of time usually accepted by geologists.

The writer does not accept this statement merely on the authority of previously published maps and the opinions of geologists who have examined the field, though the conclusion is practically the same. An active acquaintance with these rocks in the southeastern portion of Pennsylvania, during seven years of service on the Second Geological Survey of that State, had familiarized him with many of the minor characteristics which must be discovered by personal investigation and which are never found in books.

Among the reasons for ascribing these rocks to the Huronian time are some which are purely lithological, but not less worthy of attention, in the writer's opinion, because such evidence is weak when it stands alone, or because it never can have the demonstrative value of stratigraphical or other structural facts.

The Huronian series of Southeastern Pennsylvania and the adjacent parts of Maryland and West Virginia is characterized by the abundance of its chloritic rocks, which seem to form the ground-

work on which nature has wrought every grade of modification and every kind of change. These rocks appear in every intermediate variety between soft yellow-green masses of contorted leaf-like plates, giving, by the intersection of any set of edges on a plane of the specimen, wavy indications, and intersected at irregular intervals along joints or cleavage planes by masses of quartz; or containing great nodules or horses of this mineral in cavities, to the compact, hard, and fairly homogeneous rock of which the color and the indications of the edges of these small planes alone suggest any relationship to the typical chlorite slates.

The first described rock is a type which includes among its varieties all the hydro-mica schists and mica schists of this region; while the second resembles more nearly another type, long called jasper by Rogers and the earlier geologists and first clearly recognized by the analysis of Dr. T. Sterry Hunt, in 1856, as an intimate mixture of impalpably fine quartz and potash feldspar; the two mixed as they might be if hardening from a thoroughly kneaded paste. Dr. Hunt gave the name *orthophyre* to this rock, and the writer, *orthofelsite* or *orthofelsite-porphyry*, according to the form in which it appears.* Both types are found in the region of the James River under consideration, though so far as the writer's observation goes, the latter does not assume all the phases which it presents further north. As to the general lithological characters of the rocks of the east flank of the South Mountain, in Southern Pennsylvania, Maryland, and on the banks of the Potomac, and those of the Middle James River belt, they resemble each other closely.

Another point of resemblance may be noticed in the various forms of epidotic rocks which abound in the two regions. The belts, which are rich in this mineral, assume here as elsewhere the appearance of partially or entirely metamorphosed masses of which the bounding planes may or may not be sharply defined. These horizons are often cupriferous in Virginia as in other localities.

The traps of the James River are analogous to those of the more northerly areas of Huronian, though in the former they are more hornblendic, and in the latter more augitic. But both classes are met in both regions.

The quartzitic strata, which alternate with chlorites, are analogous in the two regions. This description is not intended to include the quartz conglomerate with pebbles of generally bluish or pinkish

* Besides these there are many words used as synonyms by various writers, such as *Eurite*, *Elvan*, *Petrosilex*, etc., etc.

tinge, which the writer has understood Professor Fontaine to ascribe to the Potsdam; though as to the age of this rock and its contemporaneity or non-contemporaneity with the "Mountain Creek Rock," of the South Mountain he takes the liberty of reserving judgment.

Finally, the blue magnesian limestones, speckled and flecked with white calcite, are alike in the two regions. Their age, whether Lower Silurian or not, shall not be discussed here, but it is worthy of remark that whenever an exposure is sufficiently large to permit observations of the structure, it is found that they are unconformable to the strata below them both in dip and in strike. No fossils were discovered, so that of palæontological evidence none is immediately available.

If the formation in which these James River ores occur, then, be conceded to be Huronian, it is the same as that which in Michigan contains the world-famous Marquette ores; but it is also the same as that forming part of the South Mountain in Pennsylvania, in which (micaceous) iron ore, though not entirely absent, has not yet been found in paying quantities.

GENERAL DESCRIPTION OF THE WORKS OF THE CENTRAL VIRGINIA IRON CO.

There are companies and private individuals represented in mining operations of various magnitude in this region, but as the works of the Central Virginia Iron Company were more extensive than any other, and as they were naturally more carefully studied by the writer he will pay most attention to them.

The map accompanying this paper was carefully prepared and gives, with a near approximation to nature, the relative distances and direction from each other of the various works, a general idea of the extent of the latter, and ten foot contours of the surface.

A line of transit was first run around the entire district from Horsely's Landing and Greenway wharf; the altitudes being calculated by vertical angle. Transit lines were also run from this main line to the principal works at four mining districts, viz.: *Lone Pine*, *Stapleton*, *Riverville* and *Greenway*, and from the latter to Riverville by an irregular intermediate line. When this skeleton had been completed the subordinate lines were run from it as a base by Jacob's staff and the altitudes determined by the Hicks barometer used for that purpose in the Second Geological Survey of Pennsylvania.

The unexpected time which the preparation of this map required prevented its entire completion, so that the region between Lone Pine and Stapleton is uncontoured as well as that of the sharp bend of the James River east of Greenway. The portions of the Maud, at Stapleton, of "6½," "11," and Garden Field, at Riverville; and of "16" veins at Greenway, which have been proved by exploration, are given in zig-zag lines. In the latter case the *vein* has been proved and indicated further than the *ore*.

Lone Pine.—Although a few pits and a tunnel have been undertaken here, there are—(Fall of 1881)—not enough data to interest the members of the Institute in a description of the place, further than to say that although the projectors of these works believed that they had a thirty-foot ore vein, the results so far as attained do not warrant this assertion.

Stapleton.—About three miles in a direct line northeast from Lone Pine and about eighteen miles from Lynchburg, is a point known to the old canal boatmen as Stapleton Mills. Some two miles from this point up a small stream are the mouths of two cross-cuts, which are connected with drifts on the Maud vein of iron ore. (See general map).

The vein is tolerably uniform compared with the iron-ore veins of this region, and the pay will average perhaps a foot to 16 inches to the quartz chute, at which the drift was temporarily arrested. This quartz chute deserves more than a passing notice, because it is a phenomenon too frequently connected with these ore veins, and a very good example of its kind. Like all the other chutes of barren vein-matter of this region (which are generally quartzose or quartzitic), this one sinks towards the southwest with a pretty regular pitch. It was uncovered by a winze, drift, and stope for a long distance, from about 30 feet below the level of the Maud drift to the summit of the hill. The pitch of this face was very nearly south 30° west—50°. The entire vein mass including the pay was replaced between walls by this quartz.

Some ten yards back from the present heading an interesting phenomenon was observed in the junction of a leader or string from the Maud vein called locally "No. 1 East." At the junction of the larger and smaller veins, the breadth between walls was largely increased, but there was no sign of the continuation of this vein "No. 1 East" to the westward of the Maud.

The Western cross-cut was driven from the bed of the creek and penetrates the Maud vein about 44 feet below the level of the Maud

drift and cross-cut. It has been driven about 196 feet without, as yet, crossing any chutes of barren rock.

An interesting feature of the Western cross-cut is a drift on a vein called "No. 1 West," which seems to be clearly recognizable as a fold of the Maud vein proper, and assists the judgment to a guess at the extent of these ore masses under ground, by the limitations due to the depth of their synclinals.

There are now about 2500 tons of ore in sight in this district.*

Riverville.—The mining works at Riverville are more numerous than those at any other point of the company's possessions and the production is larger.†

By referring to the maps of the Riverville district all these works will be observed. The larger number are grouped about a little stream known as Cow Branch Run, which separates the Riverside from the Edgewood farms.

On the main hill of the former, fronting the river, and upon which the dwelling of Mr. John Dillard was situated, various exploitations will be noticed, none of which have, however, been pushed to any great depth. The continuation of one of these ore-bodies across Cow Branch Run is proved by the cross-cut marked "D," which intersects a small vein very accurately on the strike of one met with in the Y-shaped drift marked "No. 6." A short drift was driven on this vein from tunnel "D."

About three-fifths of a mile northwest of the mouth of Cow Branch Run and a few hundred yards south of where it is joined by two minor streams, at an elevation of about 150 feet above the canal level at Riverville, a cross-cut has been driven into the hill for about 200 feet, which intersects vein 6½. This is called the "Hart Tunnel." The drift on this vein has been carried some 200 feet to the south-west, and 60 feet to the northeast.

In the former direction the vein was carried to its present heading

* The statements of condition of works, ore in sight, etc., in short, of all the items of a mining enterprise which vary with its progress, refer to the date at which the paper was read, viz, the Spring of 1881.

† The veins (bed-veins and contact-veins), wherever found, had been numbered according (doubtless) to some system of which the key appears to have been forgotten: at least no person whom the writer has met has been able to give a satisfactory explanation of the numbers. The principle seems to have been to number every outcrop regardless of whether there was or was not ore in sight, or whether the geological structure suggested the union of two or more of these differently numbered outcrops by synclinal or anticlinal folds. The writer has never heard veins Nos. 1 and 2 spoken of. The only numbers corresponding to ore deposits with which he is familiar are Nos. 3, 5, 6, 6½, 10½, and 11, 13 and 16.

with comparatively few interruptions from barren places or pinches. Indeed pinches of the veins are not common in this region at all, the barren spots seeming generally to be unferruginous rock matter, which replaces the ore, but leaves the walls unaltered. On the northeast drift, at about 45 feet, the ore turns to the eastward abruptly, and runs out in a short distance, the appearance of the rocks then indicating considerable disturbance.

On driving through the hanging of the vein at the extremity of the cross-cut, another small vein was met which, however, ran out when in this fifteen or twenty feet of the end of the curl just alluded to.

One hundred feet southwest of the intersection of the cross-cut with the vein, a winze was sunk about 80 feet. This gives strong indications of intersecting the chute, which cut out the ore at the northeast heading. If it be so, it follows the usual law before reverted to, of a southwest pitch to these intrusions, though in this case the angle of pitch is somewhat less abrupt being about $\pm$ 35°.

Barthold Cross-cut.—Ninety feet below the level of this Hart drift, another cross-cut has been driven to a point within a few feet of the vein where the temporary arrest of operations left it. This is called the Barthold cross-cut. It was intended to connect the winze with this cross-cut both for the better ventilation of the drift, and as a pass for the ore from the Hart drift, the product of both drifts being thus easily taken in cars from the mouth of the Barthold tunnel and transported to the Riverville landing. There are (1881) about 195 feet of stoping ground at present in the Hart drift.

Ames Tunnel.—About a mile from Riverville wharf, up the same branch (Cow Branch Run), is a drift on the so-called "No. 11" vein, which is known as the "Ames Tunnel." This tunnel (drift) when the writer first saw it, had been driven nearly 500 feet and was terminated by a heavy fall of rock. On the surface various shafts were sunk between this heading and a large one called "No. 1 shaft of No. 11 vein," and out of these smaller shafts, various amounts of ore had been taken. The large shaft "No. 1" was situated about one-third of a mile northeast of the mouth of the Ames tunnel. It was 157 feet 5½ inches deep to the lowest level, which was about 400 feet long altogether.

10½ *Shaft.*—Numerous abandoned shafts and tunnels were found in this part of the property and among others a shaft on the vein called 10½. On the drift some 18 feet above the sump of this shaft, in a sink, a very fine body of ore was observed measuring over 6 feet in breadth.

Owing to the absence of air-ways this shaft was filled with choke-damp, and could not be descended without the aid of a fan-blower during the summer months.

Garden Field Tunnel.—On the same vein and about 1200 feet from the shaft was the Garden Field tunnel, driven on fair ore for about 271 feet where it too was stopped by a heavy fall of dirt.

Canal Tunnel.—The largest of the works on the Company's land was the "Canal Cross-cut," a tunnel driven at the water-level (or very nearly so) to penetrate the Riverside hill or Canal range. The advantage of striking the veins at this low level and of bringing the ores out to the track of the newly projected and now just completed Richmond & Alleghany Railroad is apparent. This tunnel was driven through solid rock for 300 feet.

There is a total of 3806 tons of ore in sight in the works at Riverville at the present time.

Greenway.—About eight miles northeast of Riverville is the district known as Greenway. Though clearly within the prolongation of the belt of vein ores, hitherto studied at Stapleton and at Riverville, the only two veins which have been, as yet, opened upon this large property are the "John Priss" and "No. 16." Of these the latter alone will be mentioned here, the "John Priss" not having as yet received any development which would enable one to judge of its possibilities.

Five shafts have been sunk on "No. 16" and more or less connected by six levels of which the lowest (driven from the shaft "No. 4"), is 169 feet 6 inches below the surface. (See vertical section through Greenway shafts). These shafts are sunk within a linear distance of 600 feet over the surface, and in the order of their numerical progression.

The ore from "No. 16" has proved very acceptable to furnace men on account of its low percentage of phosphorus.

The portion of the vein including these shafts has been principally stoped out above the "170-foot level," but the southwest drift of the lower level is at present in a fine body of ore, of which the measurement will be found further on.

It has already been repeatedly stated that all these ore-deposits show a disposition to alternate in the line of their strike with chutes of barren (generally siliceous) rock. This "No. 16" is no exception to the rule, nor is the presence in it of chutes of richer vein-matter as well as of leaner filling, both apparently pitching from northeast to southwest *downwards*. The southwest drift heading at present is

an illustration of the more favorable of these phenomena, and the northeast headings of all the levels, of the more unfavorable.

All the northeast headings are at present in barren rock, while the southwest heading of the lower level, contains the following strata noted in a very careful section across its face.

The section is made from the northwest towards the southeast wall. The dip of the vein is nearly vertical.

	Barren.		Ore.	
	Feet.	Inches.	Feet.	Inches.
Solid ore with a few wedge-like intrusions of quartzose matter,	....	......	....	9
Barren siliceous chlorite slate, .	1	4	....	......
Good ore, ...	....	......	....	4
Barren, ...	....	3	....	......
Good ore, ...	....	......	2	6
Barren, ...	....	6	....	......
Good ore, ...	....	......	2	6
Lean ore, ...	....	......	2	0
Thickness of ore, ...	...	......	8	1
Barren rock, ...	2	1	....	......
Total width of vein, . .	10 feet 2 inches.			

The ore-body is of a thickness so exceptional in this region that it can be mined both very rapidly and in very large quantity.

At present this ore is hoisted out of "Shaft 4" by means of a steam-engine. In order to lessen the expense, it was proposed to cross-cut the hill and connect the present workings with these outlets. The works designed for this purpose will be found on the map.

Before giving the analyses of the ores hitherto mentioned, and those of the Lake Superior region by way of comparison (for which latter I desire to express my thanks to my brother member of the Institute, Mr. Charles E. Wright, of Marquette), there are a few words to say.

Without leaving the last subject of consideration,—the Greenway ores,—it should be added that the "John Priss" vein has been opened by drift in only one place, *i. e.*, from the so-called "Church Tunnel," a cross-cut entering the southeast face of the hill in which "No. 16" vein is imbedded about half a mile northeast of "No. 4 shaft," and at

the extremity of a deep and sharp ravine, immediately opposite a "negro" church (known as "Mineral Springs Church"), and about half way between "No. 4 shaft" and the partially executed "Lewis cross-cut." Here both walls, though regular, are of the same material, chlorite schist. The vein is also regular, and from three to four feet wide for the three hundred feet more or less that have been opened. But the ore where exposed is lean.

Near the extremity of the "No. 16" hill northeast, and near the Lewis cross-cut, a shaft has been sunk apparently on this same "John Priss" vein for about 40 feet. The material thrown out from this shaft shows rock, more or less stained by iron solutions, but paying ore has not yet been uncovered.

A very interesting feature of the lithology of this Greenway district is the abundance of pink, purple, and blue conglomerate, which is associated with the ore. This conglomerate is found among the ore, more or less, in all four districts (notably in Lone Pine, in the "Maud," at Stapleton, and at Riverville, both above and below the mouth of the Canal Tunnel), but nowhere are the characteristics of the rock so strongly marked as at Greenway. At the latter place it would seem to have been more thoroughly intermixed with the ore than elsewhere; but whether by metasomatic substitution of the schists with which the conglomerate already alternated, and by which it was at times replaced, or by a contemporaneous deposition with the ore itself, is not perfectly clear.

It is true, however, that the best specimens of this ore are seldom entirely clear of this rock, to which latter the high percentage of silica of *these* James River ores is due.

The pebbles of slightly violet blue, translucent quartz, sometimes in a matrix of schist and sometimes without apparent matrix, are generally rounded, but in the latter case they occasionally seem to be breccia united together by a sort of glass which allows in some cases acute angles of the fractured mineral to be seen.

GENERAL REMARKS.

All these ores show abundant evidence of their deposition by metasomatic action subsequently to the existence of the schists which enclose them.

In most cases they are little else than reproductions of the fine leaves of the chlorite or equivalent mica schists in oxide of iron which evidently resulted from a replacement of the silicates by one of the hydroxides of iron (limonite (?)) and the dehydration of this mineral

by heat (?). The quartz chutes which cut out the ore between the walls of the vein, are more difficult to explain. It has been suggested that they are intrusions of quartz in solution and suspension which followed joints in the original strata, but this hypothesis does not seem readily compatible with the observed fact that they, more frequently than not, are entirely confined to the narrow space between the walls of the vein. Whatever may be their origin, they appear to be the Kobold which haunts this series of ores very much to the depreciation of their just value.

They have been found cutting off the ore in all these districts, viz.: at Stapleton, Riverville, and Greenway; and in Riverville where most development has been made, they have been continually met and traversed. All that can be said of them is that they are liable to occur at any point, and that their direction is (so far as the author has observed), uniformly a pitch to the southwest, of from 25° to 50°.

Following are tables of analyses of these ores, as well as tables of the Lake Superior ores for comparison.

TABLE OF ANALYSES

OF THE CENTRAL VIRGINIA IRON COMPANY'S ORES, ETC.,

Made by N. ALLEN STOCKTON, during 1881.

DESCRIPTION.	WHEN SAMPLED.			IRON.	PHOS.	SILICA.
No. 6½ Ore, on Wharf, Pile II.,	March 6,			50.42	0.06	
" " " IVa.,	" "	51.89 53.66	mean,	52.77	0.04	23.00
" " " IVb.,	" "			49.80	0.06	
" " " VII.,	" "	51.00 49.10	mean,	50.02	0.05	
" " " IX.,	" "	48.95 49.30	mean,	49.12	0.04	
" Hauled, week end. Mar. 19, to Pile IVa.,	Mar. 21,			52.11	0.04	
" New Pile,	" " " "	51.38 50.82	mean,	51.10	0.05	21.05
" "	" 26, " 28,				0.04	
" "	Apr. 9, Apr. 11,	55.72 55.88	mean,	55.80	0.02	
" "	" 16, " 18,	52.86 53.40	mean,	53.13	0.045	20.33
" "	" 23, " 23,			53.9	0.04	
" "	" 30, May 3,			53.02	0.04	
" "	May 7, " 7,			52.42	0.035	
" "	" 28, " 30,			48.56	0.06	24.00
" "	June 4, June 4,	50.53 49.79	mean,	50.16	0.04	23.30
" "	" 11, " 11,	48.75 49.11	mean,	48.93	0.035	
" "	" 18, " 20,	50.94 50.39	mean,	50.66	0.035	23.00
" "	" " " 25,	53.04 52.42	mean,	52.73	0.02	

Description.	When Sampled.			Iron.	Phos.	Silica.
No. 6½ *Haulings from May 21 to June 18,	June 27,	50.53, 50.32	mean,	50.42	0.03	25.00
" Hart Tunnel Fine Ore,	Mar. 24,			56.92	0.06	
" Waste,	" "			45.55	0.08	
" Dirt mixed with ore, from Hart Tunnel, Heading of West Drift,	Apr. 4,			45.40	0.08	
" Black Dirt (Dig.) from Hart Tunnel,	" "				0.38	
" All Ore at Hart Tun. Mouth,	" 14,			50.80	0.02	
" Hart Tun. Ore, S'rtd, 1st Class,	" 18,			57.68	0.04	
" " " " 2d "	" "			49.42	0.04	
" " " Waste,	" "			30.60	0.02	
" Fine Ore, to be jigged,	" 20,			52.63	0.06	
" Pure Lump Ore (Magnetite),	" "			70.90	0.02	
" Boat Load, shipped May 12,	May 12,			49.45		
" " " " 17,	" 17,			48.16	0.035	
" " " " 23,	" 23,			48.75	0.04	
" First-class. Sorted week ending April 30,	" 3,	51.156, 51.254, 51.352	m.	51.25	0.035	
" Second-class. Sorted week ending April 30,	" "			45.27	0.035	
" First-class. Sorted week ending May 7,	" 7,			53.30	0.025	
" Hart Tun. Ore Waste, washed,	" 12,			56.65	0.45	
" Lump Ore, assorted,	June 27,	52.37, 52.43	m.	52.40	0.025	
Float ½ mile S. of Edgewood House,				56.16	0.02	17.66
Brown Hematite, ¼ mile N. 20 W. of Edgewood House,				41.99	0.34	
No. 11 Ore, on Wharf, Pile I.,	Mar. 8,			49.46	0.09	21.00
" " " III.,	" "			51.70	0.07	
" " " V.,	" 10,			50.80	0.08	
" " " VI.,	" "			47.34	0.15	21.20
" " " VIII.,	" 11.			48.10	0.10	24.70
" Scott and Adams Ore,	" 6,			52.20	0.12	
" Fine Unwashed,	" 24,			47.53	0.23	
" Washed,	" "			50.36	0.18	
" Screen Ore, Shaft No. 1,	" "			40.34		
" Wash'd Ore, W'ste, Ames Tun.,	" "					
" Ames Tunnel Ore,	Apr 4,	39.35, 35.09	m.	37.22	0.11	
" " "	" 28,			32 14	0.025	
" Sample of Ames Tun. Ore,	May 12,			38 88		
" Unlabelled Ore bro't by Carbis,	" 2,			56.45		
" Pile from Shaft No. 1, same as Pile No. VIII., sampled March 6,	June 27,	49.03, 48.76	m.	48.89	0.10	
" Hauled, week ending Mar. 19,	Mar. 21,			49.64	0.14	
" " " April 2,				49.57	0.08	
" Ames T. O., Haul. week end. May 21,	May 21,			38.79	0.05	
" Ames T. O., Haul. week end. May 28,	" 30,	48.46, 48.56	m.	48.51	0.075	28.66
" Ames T. O., Haul. week end. June 4,	June 6,	41.60, 42.93	m.	42.26	0.035	

* Average of Haulings from May 21 to June 18 = 49.72 ℔. 50.42 — 49.72 = 0.70 difference between average of all separate determinations between these dates and one determination of mixed samples.

Description.	When Sampled.			Iron.	Phos.	Silica.
No. 11 Pile from No. 1 Shaft, containing Pile VI., sampled March 6, and all No. 11 ore hauled from Mar. 12 to April 2, ...	June 27,	45.35 45.97	m.	45.66	0.14	
" Fine Ore from Pile I. unwashed, ...	April 11,	. . . .		52.83	0.08	
" " " washed,	" "	. . . .		*51.83	0.07	
" Fine Ore from Pile I. waste,	" "	. . . .		34.96	0.12	
No. 10½ Ore, Sec'n across H'd'g. G. F. T.,	" 17,	. . . .		45.07	0.06	
" From 10½ Shaft, Bot. of Winze,	" "	. . . .		37.08	0.08	
Garden Field & Ames Tunnel Ores mixed, hauled week end. May 7,	May 7,	. . . . .		42.64		
" " ending June 4.						
" " " " 11,	June 11,	44.61 45.00	m.	44.80	0.06	28.
" Haulings from April 28 to June 27,	" 27,	41.06 40.58	m.	†40.82	0.035	38.2
Maud Ore, Dump at End of Track,	March 14,	. . . . .		52.18	0.14	
" Pile West of Ore House,	" "	. . . . .		50.65	0.11	19.35
" From Vein cut in W. Tunnel,	" 19,	. . . . .		56.02	0.04	
" Large Pile on Wharf,	" 3,	. . . . .		47.30		
" Ore sent to Belmont Nail Co.,	April 17,	. . . . .		54.92	0.07	
" Ore marked "Ore not washed,"	" 24,	. . . . .		45.47	0.19	
" " "Washed Ore No. 2,"	" "	. . . . .		48.65	0.1	
" " "Washed Ore No. 3,"	" "	. . . . .		53.31	0 06	
" Fine Ore Washed (A. of 2 Det.),	May 13,	. . . . .		46.58	0.045	
" Washed Ore, ...	June 2,	. . . . .		49.79	0.085	
" Received of Prof. Frazer,	" 18,	31 73 30.98	m.	31.35	0.11	
" "Rough Ore, Washed," . .	" 21,	. . . . .		49.3		
" "Western Tunnel Ore," . .	" "	. . . . .		36.36	0.095	
" Black Dirt, ...	" "	. . . . .		13.55	0.055	
" 200 Tons of Fine Washed Ore,	July 25,	. . . . .		51.89	0.085	23.5
" 100 " Coarse Washed Ore,	" "	. . . . .		46.76	0.085	22.83
" 150 " on W. side of Ore Shed, ...	" "	52.82 53.09	m.	52.95	0.065	16.33
" 60 Tons of Western Tunnel Ore, ...	" "	37.79 37.26	m.	37.52	0.175	31.
" 4 Tons of First-class Ore, .	" "	. . . . .		48.22	0.14	
Black Dirt from Beulah Tunnel, . .	" "	. . . . .		11.55		41.66
Lone Pine Ore, Head. of Lower Drift,	Mar. 14,	. . . . .		37.7	0.04	
" Across Fall of Middle Drift, .	" "	. . . . .		27.13		
" From Upper Drift, ...	" "	. . . . .		39.95	0.03	
" From Dump, ...	" "	. . . . .		33.13	0.06	
" Specimens, ...	June 2,	. . . . .		33.59 34.05		
" Float from T. of Hill, W. of V.,	July 13,	. . . . .		54.43	0.03	13.66
Greenway Ore, Pile by Engine House,	Mar. 11,	55.26 55.26	m.	55.26	0.06	
" Pile E. of Engine House, .	" "	. . . . .		53.32	0.07	
" Specimen cont'g little Quartz,	" "	. . . . .		59.64		
" Second Class cont'g much " .	" "	. . . . .		32.26		
" Greenway Wharf, Large Pile,	" 23,	. . . . .		53.31	0.08	
" " Fine Ore, about 30 Tons, ...	Apr. 30,	. . . . .		45.37	0.075	
" Fine Ore, Washed (Average of 2 Determinations), . . .	May 25,	. . . . .		41.64	0.065	

* This ore was washed in a box, which allowed some of it to go through the cracks in the bottom.

† Average of samplings from April 28 to June 27 = 41.52 ℔. 41.52 — 40.82 = .7 difference.

Description.	When Sampled.			Iron.	Phos.	Silica.
Greenway Lump Ore en route to Charlotte Furnace, . . .	Oct. 4, ...			53.78	0.078	18.2
Ore on Lynchburg Wharf, July 23d.						
170 Tons of 6½ Ore, ...	July 23,	50.68 50.81	m.	50.74	0.040	25.83
100 Tons of Fine Maud Ore, . . .	" "	46.89 46.00	m.	46.44	0.080	22.83
50 Tons of No. 11 Ore, ...	" "	43.92 43.23	m.	43.57	0.145	
240 Tons of Maud Ore, ...	July 23,	49.74 49.55	m.	49.63	0.075	20.33
Miscellaneous:						
Hematite, North Slope of Buck Mountain,	March 13, ...			42.30	0.030	
Mud Tunnel, Dr. Mundy's, . . .	" "			55.64	0.080	
Best Float Ore, Grubb Vein Outcrop, near mouth of Slippery Gut Creek,	" "			36.70		
Ore in Place, Grubb Vein Outcrop, near mouth of Slippery Gut Creek,	" "			25.60 24.72 18.00		
Float, half way down Hill, towards Tunnel Mouth,	" "			24.70		
Limestone, near Jordan's Lane, Dr. Mundy's Property,	" 12, ...					CaO 45.08

SUNDRY ANALYSES.

Specimens from Old Shafts on Harris Property, March 11,		0.030	
March 23. Sample No. 1, "Maud Mines Sample across the face of Heading of Drift," Booth, Garrett & Blair,	45.457	0.129	
" " Sample No. 2, Maud Mine, "Section across broad part of vein, 10 ft. back from Tunnel," B., G. & Blair, ...	55.427	0.302	
June 3. No. 6½ Ore, analyzed by Chas. E. Wright, . . .	48.659	0.043	24.50

Table of Average Analyses, James River Ores.

No. of Determinations.			Description.	Iron.	Phos.	Silica.
Iron.	Phos.	Silica.				
31	31	8	No. 6½ Ore, ...	51.32	.0398	23.24
15	14	3	No. 11 Ore, ...	48.51	.118	24.1
8	6	1	Greenway Ore, ...	49.33	.071	18.2
18	17	7	Maud Ore, ...	48.43	.093	22.31
2	2	. .	No. 10½ Ore, ...	41.07	.07	. .
5	5	1	Ames Tunnel Ore, ...	39.29	.059	28.66
3	2	2	Garden Field & Ames Tunnel Mixed, .	42.75	.047	33.1
7	4	1	Lone Pine Ore, ...	37.14	.04	13.66
82	77	22	Av'ge of all the above, except Lone Pine,	48.69	.07	23.98

ANALYSIS OF IRON ORES FROM THE MENOMINEE IRON RANGE.

Name of Mine.	Insoluble Residue.	Iron.	Alumina.	Lime.	Magnesia.	Phosphorus.	Silica.	Chemist.
Emmett,	....	65.70	.72	.87	.50	.047	1.40	Chas. E. Wright.
"	....	60.33	...	3.10	1.80	.130	5.55	"
"	....	58.10	...	...	...	.025	3.80	"
Breen,	....	58.70	...	2.70	1.60	.044	4.96	"
Vulcan,	5.42	63.27	2.49	...	...	Trace.	...	Lucy Furnace Co.
"	13 96	57.64	2.30	...	...	.009	...	"
"	8.41	61 85	1.66	...	...	.017	...	"
"	9.73	61.56	.96	...	...	.018	...	"
"	8 90	63 16	...	...	...	.017	...	Cambria Iron Co.
"	12 63	60.13	.31	.09	.03	.027	.28	J. B. Britton.
"	....	62.29	...	1.31	...	.022	5.84	Chas. E. Wright.
* "	....	66 57	...	.72	...	....	1.40	"
* "	....	64 20	...	...	...	.013	...	"
Saginaw (Sec. 4),	....	58.80	2.90	2.20	3 70	.012	6 45	"
" "	....	61.30	.52	.90	.46	.009	8.90	"
" "	....	63.39	...	...	...	.074	9.80	"
" "	....	63.21	...	...	...	.011	6.50	"
Stephenson,	....	57.80	...	...	...	.094	6.60	"
Norway,	12.83	59.78	.71	...	...	.008	...	Lucy Furnace Co.
"	12.37	59.76	1.02	...	...	.008	...	"
"	15.15	57.80	1.89	...	...	.009	...	"
"	....	61.47	...	...	...	....	...	Chas. E. Wright.
"	....	59 20	...	...	...	....	4 50	"
"	....	59 64	2.30	4.10	.62	.018	7.50	"
"	....	63.50	...	...	...	.017	7.42	"
Cyclops,	4.96	65.49	1.38	...	...	.012	...	Lucy Furnace Co.
"	8.46	61 21	1.51	...	...	.014	...	"
"	8.83	60 39	1.44	...	...	.024	...	"
"	....	64.47	.95	...	...	.019	3.60	Chas. E. Wright.
"	....	67.13	.62	.36	30	.018	1.30	"
Quinnesec,	4.39	64 63	2 20	...	...	.007	...	Lucy Furnace Co.
"	4.34	64 38	2.34	...	...	.003	...	"
"	5.28	62.22	2 68	...	...	.012	...	"
"	7 61	62 66	1.19	...	...	.016	...	"
"	2.98	67.05	...	...	...	.019	...	Cambria Iron Co.
"	3 76	62.83	...	...	...	.028	...	Lucy Furnace Co.
"	4.36	65.30	1.29	.48	...	.034	...	J. B. Britton.
"	....	65.70	.83	.60	.15	.030	2.10	Chas. E. Wright.
"	....	66 18	.34	1.05	.11	.019	4.27	"
"	....	66.41	...	...	...	.017	...	"
Keel Ridge,	....	64.30	...	5.80	.97	.047	.56	"
Vermilion,	....	62.54	.44	1.22	.74	.011	4 80	"
Ludington,	....	65.80	1.52	...	...	.012	2.73	"
"	....	60.80	2.75	...	...	.020	8.30	"
Chapin,	....	68.88	...	1.04	...	.010	...	"
"	....	64 57	...	.74	...	.012	...	"
Sec. 32, T. 42, R. 29,	....	69.10	...	...	...	.015	.55	"
" " "	....	67.04	...	...	...	.020	3.20	"

AVERAGE OF EACH MENOMINEE MINE PER PRECEDING TABLE.

Name of Mine.	Iron.	Phos.	Silica.
Emmett,	61.38	.067	3.58
Breen,	58.70	.044	4.96
Vulcan,	62.30	.015	2.51
Saginaw,	61.67	.026	7.91
Stephenson,	57.80	.094	6.60
Norway,	60.16	.012	6.47
Cyclops,	63.74	.017	2.45
Quinnesec,	64.74	.018	3.18
Keel Ridge,	64.30	.047	.56
Vermilion,	62.54	.011	4.80

* New opening on Section 9.

Name of Mine.	Iron.	Phos.	Silica.
Ludington, ...	63.30	.016	5.51
Chapin, ...	66.72	.011	. .
Sec. 32, T. 42, R. 29, ...	68.07	.017	1.87
Average of 48 Determinations Iron, 45 Phosphorus, and 25 Silica.			
	Iron.	Phos.	Silica.
Menominee Ores, as above, ...	62.88	.023	4.49

ANALYSES OF IRON ORES FROM THE MARQUETTE REGION.

Name of Mine.	Metallic Iron.	Alumina.	Lime.	Magnesia	Silica.	Phos.	Sulph.
Cleveland, ...	66.50	1.20	.90	.40	1.90	.075	.018
Lake Superior, ...	66.10	1.05	.85	.30	2.40	.06	.02°
New York, ...	65.50	2.10	.80	.35	3.00	.120	.035
Champion, ...	67.10	1.20	.80	.70	1.50	.035	.020
Republic, ...	67·30	.80	.50	.45	2.00	.060	.020
Boston, ...	67.10	.90	.40	.50	1.40	.015	.015
Milwaukee (Hematite), ...	63.10	1.70	.80	.70	2.50	.070	. .
Columbia, ...	65.40	1.00	.25	.30	3.10	.070	.020
Average of 8 Determinations Iron, Phosphorus and Silica, Marquette Ores, as above, ...	66.01				2.22	.063	

Average Analysis of all Lake Superior Ores, per 2 Preceding Tables.

	Iron.	Phos.	Silica.
56 Determinations of Iron, 53 of Phosphorus, and 33 of Silica,	63.33	.0293	3.40

PROCEEDINGS

OF THE

ANNUAL MEETING IN BOSTON.

FEBRUARY, 1883.

BOSTON MEETING.

Local Committee of Arrangements.

General F. A. Walker, *Chairman;* Professor R. H. Richards, *Secretary;* Professor A. Agassiz, Mr. Edward Atkinson, Mr. G. H. Billings, Mr. J. Caleb Bartlett, Mr. Albert S. Bigelow, Messrs. Bacon & Co., Professor C. R. Cross, Mr. Hugh Cochrane, Mr. Samuel Crocker, Mr. Howard A. Carson, Mr. W. O. Crosby, Professor Josiah P. Cooke, Mr. Thomas Doane, The Deane Pump Company, Professor W. M. Davis, Mr. W. E. C. Eustis, Mr. E. S. Eaton, Mr. H. L. Eaton, Professor H. L. Eustis, President Charles W. Eliot, Messrs Fiske and Coleman, Mr. James B. Francis, Mr. William Foster, Mr. S. M. Felton, Jr., Mr. Charles Fairchild, Mr. Walter Faxon, Mr. George Gogin, Professor Wolcott Gibbs, Mr. Hamilton A. Hill, Mr. F. L. Higginson, Mr. Albert F. Hall, Mr. Henry L. Higginson, Mr. H. M. Howe, Professor A. Hyatt, Professor H. B. Hill, Professor C. Loring Jackson, Mr. C. W. Kettell, Mr. Henry P. Kidder, Professor G. Lanza, Mr. E. D. Leavitt, Jr., Professor Joseph Lovering, Mr. Henry Manly, Mr. Thomas Minns, Mr. Philip W. Moen, Mr. Charles H. Morgan, The National Tube Works, Professor W. H. Niles, The Norway Iron Works, Professor J. M. Ordway, Mr. Edward S. Philbrick, Mr. Charles O. Parsons, Mr. M. D. Ross, Professor S. P. Sharples, Mr. William E. Sparks, Professor N. S. Shaler, Mr. James P. Tolman, Professor John Trowbridge, Professor G. L. Vose, Mr. Henry M. Wightman, and Professor M. E. Wadsworth.

The opening session was held in the Hotel Brunswick, on Tuesday evening, February 20th. Mr. E. D. Leavitt, Jr., of the Local Committee of Arrangements, introduced Mr. Edward Atkinson, who, after assuring the members present of a hearty welcome to Boston, spoke of the progress of mining and metallurgical industries in the United States, and of their relation to these industries abroad.

Mr. Leavitt then introduced Mr. Thomas Doane, President of the Boston Society of Civil Engineers. Mr. Doane welcomed the Institute on behalf of the engineers of Boston, who extended to the members present the hand of fellowship, both as individuals and as a corporation.

President Rothwell replied for the Institute, to the cordial addresses of Mr. Atkinson and Mr. Doane, and opened the session of the Institute, by calling for a paper by Mr. J. C. Bayles, of New York, on the "Microscopic Analysis of the Structure of Iron and Steel." Dr. T. Sterry Hunt, of Montreal, followed, in reading a paper on the "Coal and Iron of Alabama."

The following persons, proposed for members and associates of the

Institute, and approved by the Council, were then unanimously elected:*

MEMBERS.

Thomas S. Austin,	Stratford, Conn.
Edward Bailey, Jr.,	Harrisburg, Pa.
Alfred L. Beebe,	New York City.
William de L. Benedict,	New York City.
Anthony S. Bower,	St. Neots, England.
William H. Bradley,	Chicago, Ill.
Herbert C. Burchell,	Sydney, Cape Breton, N. S.
James T. Burchell,	Sydney, Cape Breton, N. S.
Charles Butters,	New York City.
Cornelius Cadle, Jr.,	Montevallo, Ala.
James M. Camp,	Allegheny, Pa.
George H. Clapp,	Pittsburgh, Pa.
M. Claypool,	Georgetown, Col.
Alexander Colvin,	Greeley, Col.
William H. Cooper,	Jersey City, N. J.
F. D. Cummer,	Cleveland, O.
James S. Cunningham,	Midvale, N. J.
William S. Dalliba,	Chicago, Ill.
William F. Downs,	Jersey City, N. J.
John Duff, Jr.,	Boston, Mass.
W. H. Graff,	Pittsburgh, Pa.
John W. Griswold,	Troy, N. Y.
Herbert Hackney,	Portland, Oregon.
B. F. Haldeman,	McKeesport, Pa.
John Heard, Jr.,	Washington, D. C.
C. Hanford Henderson,	Philadelphia, Pa.
Frank A. Hill,	Wilkes-Barre, Pa.
Herman Hollerith,	Boston, Mass.
Augustus E. Knorr,	Washington, D. C.
William A. Lathrop,	Pocahontas, Va.
Charles J. Lincoln,	Boston, Mass.
Richard W. Lodge,	Boston, Mass.
Robert W. Mahon,	Easton, Pa.
William Martyn,	Elizabeth, N. J.
Samuel W. McKeown,	Youngstown, O.
Carl Meyer,	Denver, Col.
Frank P. Mills,	Crystal Falls, Mich.
H. B. Nason,	Troy, N. Y.
Maurice B. Patch,	Houghton, Mich.
W. A. Perry,	New York City.
Samuel Peters,	Portland, Me.
Axel E. Petre,	Nicetown, Philadelphia, Pa.
John B. Porter,	Glendale, O.

* This list includes those members and associates who were elected at a subsequent session of the meeting.

Thomas B. Provis,	London, England.
Eugene N. Riotte,	New York City.
John George Rutherford,	Albion Mines, N. S.
Meyer Schamberg,	Philadelphia, Pa.
William H. Shockley,	Candelaria, Nevada.
H. N. Sims,	Pottsville, Pa.
James Todd,	Allegheny, Pa.
Alexander Trippel,	New York City.
John C. Walker,	Chicago, Ill.
George D. Whitcomb,	Chicago, Ill.
William A. Wilson,	Park City, Utah.

ASSOCIATES.

Frederick E. Buckingham,	Brooklyn, N. Y.
William F. Burden,	Troy, N. Y.
Floyd Davis,	Rolla, Mo.
Anthony Fischer,	Philadelphia, Pa.
John D. Fleming,	Leadville, Col.
Walter C. Hadley,	Las Vegas, N. M.
G. H. Heywood,	Boston, Mass.
James M. Hibbs,	Philadelphia, Pa.
John P. Logan,	Philadelphia, Pa.
William P. Moore,	New York City,
Charles F. Pearis,	New York City.
George W. Stetson,	New York City.
George W. Stevens,	Chicago, Ill.
Arthur K. Watt,	Easton, Pa.
W. Dewees Wood,	Pittsburgh, Pa.

The status of the following associates was changed to membership: George Aucby, Richard D. Baker, F. G. Corning, C. W. Davenport, W. H. Emanuel, R. P. Field, E. H. Garthwaite, N. H. Muhlenberg, Edgar Richards, and Ferdinand Sands.

The President appointed Messrs. Richard D. Baker, R. C. Canby, and Wheaton B. Kunhardt scrutineers, to examine the ballots for officers of the Institute, and report at a subsequent session.

At the second session, on Wednesday morning, at the Massachusetts Institute of Technology, the following papers were read and discussed:

Block Tin Resulting from Distillation of Tin Amalgam, by Professor R. H. Richards, of Boston.

A Suggested Cure for Blast Furnace Chills, by H. M. Howe, of Boston.

The Metallurgy of Nickel in the United States, by Professor W. P. Blake, of New Haven, Conn.

The Bower-Barff Process for Making Rustless Iron, by A. S. Bower, C.E., St. Neots, England.

After the adjournment of this session, an excursion was made in omnibuses, provided by the Local Committee, to the Leavitt sewage pumping engines, one of which was put in operation for the benefit of the visitors. The engine, as well as the design and extent of the works at the Calf Pasture, for the disposal of the sewage, was described by Mr. E. D. Leavitt, Jr., and Mr. H. M. Wightman. The party next went to the Norway Iron Works, which were inspected under the guidance of Mr. G. H. Billings and Mr. George W. Gogin. Mr. Billings's process of cold-drawing, and the method of using petroleum as fuel, were exhibited. On leaving the Norway works the sewer excavating apparatus of Mr. H. A. Carson was shown by the inventor in operation in the streets of the city.

The third session was held on Wednesday evening, at the Institute of Technology, when the following papers were read:

Jacketing of Roasting Cylinders at Deloro, Canada, by R. P. Rothwell, of New York city.

The Geological Relations of the Topography of the South Appalachian Plateau, by Professor W. C. Kerr, of Washington, D. C.

The Collection of Flue-dust at Ems, by Dr. T. Egleston, of New York city.

Lines of Weakness in Cylinders (illustrated by blowing glass cylinders), by Professor R. H. Richards, of Boston.

The Management of Structural Steels, by A. F. Hill, of New York city.

Letters were read by the Secretary from President Freeman, of Wellesley College, inviting the Institute to visit the college; from Mr. Edward Burgess, Secretary, and Professor Alpheus Hyatt, Curator, of the Boston Society of Natural History, offering the use of the library of the Society to the members during their stay in Boston, and the privilege of a private inspection of their collections; and from General Charles E. Loring, who sent complimentary tickets of admission to the Boston Art Museum.

Dr. R. W. Raymond, chairman of the joint committee of the three engineering societies, on the Holley Memorial, and also chairman of the sub-committee, reported that the subscription to the Central Park monument was yet open. He also reported progress on the Holley Memorial Volume.

On Thursday morning a large number of members were taken in omnibuses to Watertown Arsenal, where they were received by Captain John G. Butler, of the Ordnance Department, who exhibited the great testing machine, and showed the method of its operation and registering strains. The party then proceeded to Harvard University, where they were kindly escorted to the buildings and collections of interest by Professor W. E. Byerly. Professor Joseph Lovering received the party in Harvard Hall, Dr. Justin Windsor in the Library, Dr. D. A. Sargent in the Hemenway Gymnasium, Professor John Trowbridge in the Physical Laboratory of the Lawrence Scientific School, Professor W. M. Davis at the Museum of Comparative Zoology, and Professor F. W. Putnam at the Peabody Museum. The members then assembled in Sanders's Theatre, and were greeted by Professor N. S. Shaler, who extended to them a cordial and graceful welcome on behalf of the university. Lunch, provided by the Local Committee, was then served in Memorial Hall. Professor Cooke's chemical laboratory and mineral collections in Boylston Hall were next visited, and a session of the Institute was held in the lecture-room. Professor S. P. Sharples read a paper on "Experiments on American Woods," after which, Professor Cooke kindly exhibited the critical point of carbonic acid, by projecting on a screen an image of a tube containing liquid carbonic acid, by means of a lantern and the electric light. After President Rothwell had expressed the thanks of the Institute to Professor Cooke for his beautiful experiment, the session adjourned.

In the evening a subscription dinner was held at the Hotel Brunswick.

The final session was held on Friday morning, at the Institute of Technology. Dr. Persifor Frazer read a paper on the "The Eozoic and Lower Palæozoic in South Wales, and their Comparison with their Appalachian Analogues."

The Secretary read the following:

REPORT OF THE COUNCIL.

In accordance with the rules, the Council makes the following report to the Institute:

The financial statement of the Secretary and Treasurer, duly audited, shows receipts for the year from all sources of $13,169.05, and expenditures of $8140.53, leaving a surplus for the year of

$5028.52. There has been a considerable increase of the receipts over last year, owing mainly to the largely increased membership and life-membership; and the payments for publications have been less than last year. The detailed statement is as follows:

Secretary's and Treasurer's Statement of Receipts and Disbursements from February 1st, 1882, to January 31st, 1883.

Dr.

Balance at last statement,	$218 64	
Received for dues from members and associates,	10,020 00	
" for life-memberships,	1,200 00	
" from sale of publications,	1,102 00	
" for binding *Transactions*,	378 75	
" for author's pamphlets,	106 75	
" for electrotypes,	28 60	
Interest on U. S. bonds,	36 00	
Interest on deposits,	78 31	
		$13,169 05

Cr.

Paid for printing vol. x. *Transactions*,	1,270 29	
" binding vol. x. *Transactions*,	400 86	
" printing pamphlet edition of papers,	895 75	
" printing author's edition of papers,	91 25	
" printing lists of members,	30 00	
" printing circulars, etc.,	104 75	
" binding back volumes of *Transactions*,	89 25	
" binding exchanges,	48 75	
" engraving,	348 50	
" electrotyping,	11 75	
" postage,	765 60	
" freight and expressage,	113 30	
" stationery,	55 08	
" telegrams,	24 81	
" insurance,	37 50	
" rent of office,	120 00	
" storage of *Transactions*,	50 00	
" one-third expenses of Holley Memorial Session, in New York,	20 00	
" Secretary's salary,	2,500 00	
" Secretary's assistant's salary,	750 00	
" Secretary's and assistant's expenses at meetings,	378 89	
" incidental expenses of Washington meeting,	34 20	
		8,140 53
Excess of receipts over expenditures,		$5,028 52

This surplus will be funded by the Finance Committee of the Institute.

The tenth volume of *Transactions* has been issued and distributed as usual. It is proposed to prepare in the near future, an Index to volumes i. to x., and to publish it in a separate volume.

The annual meeting of 1882 was held in Washington, D. C. The other two meetings required by the Rules, were combined in the Colorado meeting in August. Notwithstanding the great distance from the homes of the majority of the members, the Colorado meeting was very largely attended, and was memorable for its great professional profit, as well as for its delightful excursions. Our Colorado members, and the citizens of the State generally, extended to the visiting members a cordial welcome, and entertained them with a generous and graceful hospitality.

The professional papers of the year have been numerous and valuable, and it is to be mentioned with satisfaction, that a larger number than usual relate to the mining, milling, and smelting of the ores of the precious metals.

There were elected at the two meetings, 215 members and 62 associates. During the year 10 members have resigned, and 25 have been dropped from the roll for non-payment of dues. Eight members have died: David Thomas, Robert Briggs, W. S. Dwight, C. M. Wheatley, Ashbel Welch, H. E. Wrigley, and W. I. Whilldin. The membership of the Institute now comprises 5 honorary members, 50 foreign members, 1009 members, and 149 associates, a total of 1213.

The Scrutineers appointed at the first session of the meeting presented their report, declaring the following persons elected officers of the Institute:

PRESIDENT.

Robert W. Hunt, ... Troy, N. Y.

VICE-PRESIDENTS.

(To serve until February, 1885.)

S. F. Emmons, ... Denver, Colo.
W. C. Kerr, ... Washington, D. C.
S. T. Wellman, ... Cleveland, O.

MANAGERS.

(To serve until February, 1886.)

John Birkinbine, ...	Philadelphia.
Stuart M. Buck, ...	Coalburgh, W. Va.
E. S. Moffat, ...	Scranton, Pa.

TREASURER.

Theodore D. Rand, ...	Philadelphia.

SECRETARY.

Thomas M. Drown, ...	Easton, Pa.

A motion to change Rule VI., limiting the regular meetings to two in the year, was laid on the table.

Mr. Bayles spoke of the courteous attention the Institute had received during the meeting from individuals, societies, colleges, and business corporations, and of the admirable arrangements and hearty hospitality of the Local Committee, and offered a resolution, which was unanimously adopted, that the Secretary be instructed to convey the thanks of the Institute to those who had so kindly contributed to the profit and enjoyment of the meeting.

The following papers were then read by title:

A New Hydraulic Separator to prepare Ores for Jigging and Table Work, by Professor R. H. Richards, of Boston.

Occurrence of Gold in Williamson County, Texas, by Professor C. A. Schaeffer, of Ithaca, N. Y.

Water-gas as Fuel, by W. A. Goodyear, of New Haven, Connecticut.

The Natural Coke of Chesterfield County, Virginia, by Dr. R. W. Raymond, of New York city.

On the Utility of the Method of the Pennsylvania State Geological Survey in the Anthracite Fields, by Benjamin Smith Lyman, of Northampton, Mass.

Gas-Producer Explosions, by P. Barnes, of Elgin, Ill.

Ice Mining and Storing, by Professor W. P. Blake, of New Haven, Conn.

The Mining Region about Prescott, Arizona, by J. F. Blandy, of Prescott.

Blast-furnace Practice, by C. Constable, of New York city.

Note on a Protected Hot-blast Stove, by F. Firmstone, of Easton, Pa.

Notes from the Literature on the Geology of Egypt, and Examination of the Syenitic Granite of the Obelisk which Lieutenant-Commander Gorringe, U.S.N., brought to New York, by Dr. Persifor Frazer, of Philadelphia.

The Geology of Cape Hatteras and the South Atlantic Coast, by Professor W. C. Kerr, of Washington, D. C.

The Divining Rod, by R. W. Raymond, of New York city.

Notes on the Linkenbach Improvements in Ore-Dressing Machinery used at Ems, by R. P. Rothwell, of New York city.

The Determination of Manganese in Spiegel, by G. C. Stone, of Newark, N. J.

Gas Analysis, by Magnus Troilius, of Philadelphia.

Determination of Copper in Steel, by Magnus Troilius, of Philadelphia.

History and Statistics of the Manufacture of Coke, by J. D. Weeks, of Pittsburgh, Pa.

Notes on Settling Tanks in Silver Mills, by A. Williams, Jr., of Washington, D. C.

President Rothwell expressed his thanks to the members of the Institute for their support during the year, and congratulated them upon the character of the work done, and after wishing for his successor as pleasant an administration as his own had been, declared the annual meeting of 1883 adjourned.

After the adjournment of the meeting an excursion was made, by special car, offered by the Boston and Lowell Railroad Company, to Lowell, where, on arrival, the members were kindly entertained at lunch by Mr. and Mrs. J. B. Francis. Mr. Francis, the manager for the proprietors of the locks and canals, then took the party to the water-power, and explained the method of its utilization. Visits were afterwards made, under the guidance of Mr. Francis and Mr. J. S. Ludlam, to the mills of the Lowell Carpet Manufacturing Company, the Lawrence Manufacturing Company, and the Merrimac Manufacturing Company, where the members received polite attention from the proprietors and managers.

The following members and associates were present at the meeting:

John S. Alexander.
E. C. Appleton.
William Atkins.
W. Lawrence Austin.
Richard D. Baker.
James C. Bayles.
G. H. Billings.
W. P. Blake.
William F. Biddle.
H. T. Bovey.
Anthony S. Bower.
G. W. Bramwell.
William Burnham.
Charles Butters.
F. von A. Cabeen.
R. C. Canby.
Townsend Church.
F. W. Clark.
Charles E. Coffin.
C. Constable.
F. H. Daniels.
T. M. Drown.
T. Egleston.
S. F. Emmons.
W. E. C. Eustis.
J. W. Farquhar.
Edward L. Ford.
R. Forsyth.
Persifor Frazer.
John Fritz.
William Glenn.
George W. Gogin.
W. A. Goodyear.
F. J. Hearne.
A. F. Hill.
H. Hollerith.
H. M. Howe.
W. S. Hungerford.
F. F. Hunt.
Robert W. Hunt.
T. Sterry Hunt.
Axel O. Ihlseng.
E. P. Jennings.
W. C. Kerr.
C. Kirchoff, Jr.
Wheaton B. Kunhardt.
L. G. Laureau.
E. D. Leavitt, Jr.
Nicholas Lennig.
Samuel W. Lewis.
Charles J. Lincoln.
S. Lindsley.
Richard W. Lodge.
Joseph S. Ludlam.
Jean A. Mathieu.
W. F. Mattes.
G. W. Maynard.
James H. Mayo.
Walter McDermott.
P. W. Moen.
J. M. Ordway.
John H. Paddock.
E. M. Parrott.
Charles O. Parsons.
S. Peters.
A. C. Rand.
R. W. Raymond.
Ellen H. Richards.
R. H. Richards.
J. H. Ricketson.
Percival Roberts, Jr.
R. P. Rothwell.
H. H. Sawyer.
O. P. Scaife.
W. H. Sears.
S. P. Sharples.
John M. Sherrerd.
Porter W. Shimer.
J. William Smith.
Herbert G. Torrey.
S. T. Wellman.
H. A. Wheeler.
Arthur Winslow.

PAPERS

OF THE

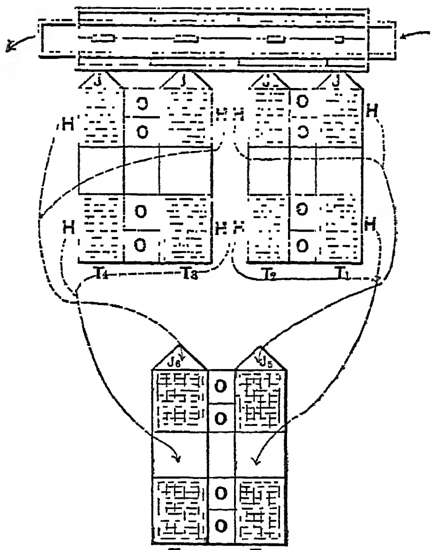
BOSTON MEETING.

FEBRUARY, 1883.

A NEW HYDRAULIC SEPARATOR TO PREPARE ORES FOR JIGGING AND TABLE WORK.

BY ROBERT H. RICHARDS, S.B., PROFESSOR OF MINING, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, BOSTON, MASS.

During a stay in one of the crushing and washing mills of Lake Superior I had occasion to study the losses of copper in the sands. I very soon made up my mind, as I afterwards found that every copper man on the Lake had done, that the form of separator used there was not as satisfactory as could be desired. The universal criti-



T6 Fig.1 T5

cism appeared to be that this machine does not efficiently separate the fine copper from the coarse material. For instance, if the letters J_1, J_2, J_3, J_4, in the diagram (Fig. 1)* represent the four feed-spigots to the jigs, from the old form V-shaped separator, J_1

* For the description of the Lake Superior separator, see article by C. M. Rolker, Transactions, vol. v., p. 584.

being the coarsest and J_4 the finest; H, H, etc., being the hutch-work or siftings; T_1, T_2, etc., being the tails of the respective jigs; and J_5 and J_6 finisher jigs, then the effect of imperfect separation would be to allow some fine copper to come on jig J_1, which is too fine for this coarse jig to treat, and which is therefore lost in the tails, T_1. This copper ought never to have found its way to jig J_1, but should have been retained in the overflow of the separator and thence have gone to the tables. The same is also true of jigs J_2, J_3, J_4.

If the hydraulic water be increased on this form of separator, that is, the V separator, it is found that it sends a large share of coarse sand over on the finer jigs, J_2, J_3, J_4, and even to the tails of

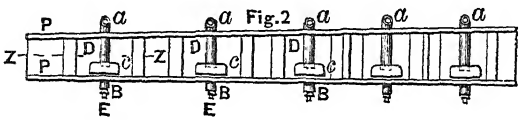


Fig. 2

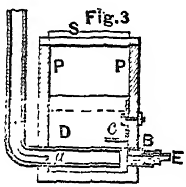


Fig. 3

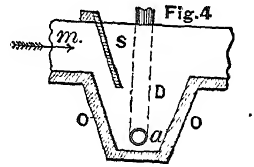


Fig. 4

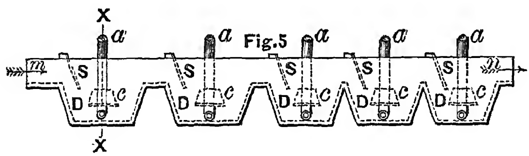


Fig. 5

the separator. This evil will be greater or less, according to the amount of water used.

Between this difficulty and the former there appears to be no well-defined line to guide the washer and to show him whether he is losing more copper by the one or the other cause.

With a view to overcome this difficulty a separator has been devised, of which the accompanying diagrams (Figs. 2, 3, 4, and 5) represent the construction. It consists of four or five boxes, D, D, etc., or depressions in the bottom of a continuous trough. The water and sand enter at m and undergo successive washings in each box until the fine sand overflows at n.

The operation in each of the boxes is as follows: the heaviest

sand at once finds its way to the bottom of the box; the wash-water is brought in through the pipe, *a*, in greater quantity than is sufficient to supply the spigot, E. No sand, therefore, can find its way out through E that has not weight enough to stem this water-stream. This excess of water also acts by keeping the whole bottom of the box in a boil and turmoil, thus ever pushing up the lighter sands and allowing the heavier to keep near the bottom. The shield, *c*, plays an important part here, by preventing the stream from rising straight up, and thereby confining the turmoil to the bottom of the box, where it belongs. The stop, S, is of importance to prevent the sand from jumping a box altogether, as it might do if the current was a little too strong.

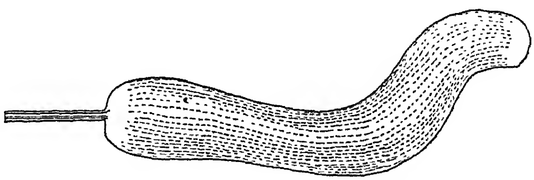
Referring back to Fig. 1 for the letters, this new separator has accomplished the following results: (1.) T_1, T_2, T_3, T_4 may be said to be practically free from the fine copper now, which, therefore, finds its way to the separator-overflow and thence to the tables. This is so completely done that the water on jigs 1, 2, 3, and 4 is no longer muddy, but is clear, like that on the finished jigs. (2.) The coarse included copper is no longer sprinkled over jigs 1, 2, and 3, as oftentimes with the old form. This included copper comes almost wholly on jig No. 1, and, therefore, if it is a product of sufficient magnitude to be of commercial importance we have it much concentrated in T_1, and can there put in an appliance for saving it. T_2, while much cleaned of this grade of sand, is not wholly cleaned and may need more attention, though it is far inferior to T_1. (3.) The several spouts are now perfectly under control. A slight increase or decrease in the wash-water will respond with great readiness in the quality of the spigot sand. (4.) The separator has been proved to use less water than the old form, which is not only an economy in pumping but also lessens, appreciably, the number of tables required for the separator-overflows.

Finally, in places where two minerals only have to be separated, and where the cost of sizing sieves as a preliminary operation is too great, this separator appears to be the next best thing that has come to my notice. In fact, it has the advantage of sizing sieves, as preliminary, in one respect, and that is that we are not obliged to jig one size of sand by itself. With the separator we use mixed sizes, causing a great saving of water on the coarser jigs, over what they would use with the preliminary sizing by sieves.

AN ILLUSTRATION OF THE LINES OF WEAKNESS IN CYLINDERS.

BY ROBERT H. RICHARDS, S.B., PROFESSOR OF MINING, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, BOSTON, MASS.

It has long been known to boiler makers and to the users of cylindrical pipes of many kinds that when a tube is exposed to internal fluid pressure the resolution of forces is such that the material of the walls of the tube is exposed to twice the stress in the direction tending to produce longitudinal rupture, as it is in the direction to produce circumferential fracture. By longitudinal fracture is meant the fracture by a rent parallel to the axis; by circumferential fracture is meant fracture by rents running round the cylinder. In consequence of this the makers of boilers always lay the fibre of their metal in direction round the boiler, and the same is true with the makers of gun-barrels.



I have never seen any good and simple illustration of this law until I met with it in blowing glass. If a thin bubble of glass be blown out in a spherical form and then exploded it will be found that the particles tumble into totally irregular shapes, showing no special direction in the molecular structure of the material. If now a bubble of glass be blown out and so manipulated that it will take a cylindrical form (see accompanying illustration), and then be exploded, it will drop into ribbon-shaped pieces from end to end, and the only parts that will be found to differ from this form will be the two hemispherical ends which will remain whole, having a fringe of ribbons representing the line of their fracture from the cylinder.

The main point of difference between this experiment and the

accidental explosion of large boilers appears to be that in a boiler the shell yields at its weakest point, and once the rent is started it tears the boiler to pieces without much regularity of lines, while in the glass cylinder the walls are so nearly of the same strength that it can hardly be said to have a weakest point. When, therefore, it gets to its limit of strength, and is on the verge of exploding, there is no one place to initiate the explosion, and the glass explodes all over. This it does, as it should do, by tearing into innumerable ribbons parallel to the axis of the cylinder.

If P = the pressure and D = diameter of cylinder, then

$\frac{P\,D}{2}$ = stress tending to longitudinal rupture, and

$\frac{P\,D}{4}$ = stress tending to circumferential rupture.

BLOCK TIN RESULTING FROM DISTILLATION OF A TIN AMALGAM.

BY ROBERT H. RICHARDS, S.B., PROFESSOR OF MINING, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, BOSTON, MASS.

IN the latter part of December a batch of amalgam was retorted and the tin in the retort uncovered while at a low red heat, and allowed to cool slowly to a temperature more suitable for ladling into moulds. It was then ladled and made what appeared to be nice, white, malleable block tin.

On February 15th our attention is called to the fact that the tin is brittle, and on examination we find that the molecular condition of the pigs has changed to the extent of one-half its material. The change shows itself by an enlargement appearing on the surface something like crystallization, and comes in spots. The condition of the metal in these spots is very peculiar. It has changed from a malleable metal to a brittle one, with a structure somewhat resembling stibnite, and a color very considerably darker gray than tin.

The analyses of the two parts of this tin pig showed the following results:

	Mercury.	Tin.	Specific Gravity.
Crystalline part,	2.62	97.24	6.175
Malleable part,	2.38	97.50	7.387

I think it very probable that this crystallization of tin, which appears to be due to 2.62 per cent. of mercury, owing to imperfect retorting, may be well-known to some of the members of the Institute, but as it was unknown to me, I have presumed to present the matter at this meeting.

This metal was produced by Messrs. G. R. Underwood and David Wesson, and the analyses were made by them.

COAL AND IRON IN ALABAMA.

BY T. STERRY HUNT, LL.D., F.R.S., MONTREAL, CANADA.

COAL was mined to a small extent near Tuscaloosa, in Alabama, and even carried by boats to Mobile, half a century since. Professor Porter, and later, Professor R. T. Brumby, occupied themselves with the geology of the region, and it attracted the attention of Sir Charles Lyell, who visited the region. It is, however, to the two reports of Professor Tuomey, geologist to the State, published in 1850 and 1858, that we owe our first clear notions of the geology of the Alabama coal-fields. His work has, since 1873, been continued by Professor Eugene A. Smith, of the University of Alabama, whose valuable reports, extending and completing the work of his predecessor, are indispensable guides to the geological inquirer in this region. Mention should also be made of the investigations of Mr. R. P. Rothwell, who, after three years of studies in parts of the Alabama coal-fields, read before the American Institute of Mining Engineers, in October, 1873,* a brief but important paper calling attention to the great deposits of coal and iron-ore found therein, and to their economic importance. Having myself, during the past year, had an opportunity of visiting parts of this region, I have thought that it might be well to bring before the Institute some facts and considerations as to its geological and geographical characteristics, and the value of its mineral resources.

It is well known that the great Appalachian coal-basin, stretching southwestward through western Tennessee and the northwestern corner of Georgia, terminates in northern Alabama in what is called the Warrior coal-field, which there covers an area of about 5000 square miles. Lying along the southeast border of this, but

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* *Transactions*, vol. ii., pp. 144–157.

separated by a narrow belt of older rocks, is the Cahaba coal-field, having an area of about 230 square miles; while to the northeast of this, and near it, is the Coosa field, a little known area of about 300 square miles. These smaller fields were evidently at one time continuous with the greater one to the west, and belong to the great Appalachian basin, from which they have been separated by folding, faulting, and erosion. They are narrow, and elongated in a northeast and southwest direction.

Along the southeastern border of these coal-fields in Alabama extends a broad valley drained by the Coosa River, of which it bears the name. This is the southwestern extremity of the great Appalachian Valley, which stretches continuously from the Hudson, through Pennsylvania, Virginia, Tennessee, and Georgia. The ancient crystalline rocks of the Atlantic belt—seen in New England, the Highlands of the Hudson, the South Mountain of Pennsylvania, and the Blue Ridge—which form the southeastern border of the Great Valley, are still found in their place, limiting the Coosa Valley, until we reach the centre of Alabama. The northwestern border of this valley is here defined by the eastern edges of the Coosa, Cahaba, and Warrior coal-fields, and appears in Lookout Mountain, near Chattanooga. The valley thus limited has a breadth varying from fifteen to thirty miles or more, and is furrowed by many subordinate parallel ridges.

In central Alabama, the crystalline rocks on the one side, and the coal measures on the other, alike sink down and disappear beneath the transverse belt of quaternary deposits known as the Orange Sand, which conceals the contact between the older rocks and the overlying Cretaceous strata lying to the southward.

It is instructive to one acquainted with the great geognostical and geographical divisions of the Middle States to follow these southward till they are lost in the manner just described beneath the broad plain of the Gulf States. The great Appalachian coal-basin in Pennsylvania, Ohio, West Virginia, and Kentucky is, as is well known, tributary to the Ohio, through which its waters pass by the Mississippi into the Gulf of Mexico. It has for this reason been not inappropriately called the Ohio coal-basin. Along its eastern border stretches the double mountain-belt of the Alleghenies and the Blue Ridge or Atlantic belt, which separates the coal and iron from the tidal waters of the Atlantic coast. But in Alabama we reach the southern extremity of these mountain ranges; we find the barrier broken down, and the southern part of the vast Ohio coal-basin

drained by navigable rivers flowing through a great plain to the Gulf of Mexico.

The detached coal-fields along the eastern border of the great basin, which are seen from Pennsylvania to Alabama, are often designated as outliers, and Professor Smith has aptly described the valleys with lower rocks, limiting these subordinate coal-fields, as outliers of the Coosa Valley. These, which have the northeast and southwest direction of the latter, are, first, the Cahaba Valley, separating the Coosa and Cahaba fields; second, the Long Valley, as it is called, which separates the Cahaba from the Warrior field, and extends from below Tuscaloosa northward to Village Springs, beyond which it bifurcates, the western branch running to Sand Mountain, which terminates the valley, and the other running northeast into Georgia and Tennessee.

It is along this valley that the Alabama Great Southern Railroad passes from Chattanooga to Birmingham, and thence nearly to the southwestern end of the valley, where the railroad turns westward to Tuscaloosa, at the southeastern extremity of the Warrior coal-field. It will further aid us in forming a notion of the geography of this region if we bear in mind that the Selma, Rome, and Dalton Railroad, nearly parallel with the last, runs from the crossing of the Coosa River northward, within the Coosa Valley, and from eight to ten miles to the westward of the crystalline range which forms the eastern boundary of this valley.

There remains to be noticed a third outlying valley, farther west than those already mentioned, and known as Brown's Valley. This, which is a prolongation of the great Sequatchee Valley of Tennessee, does not extend far southward, but dies out at Blount's Springs, in the Warrior coal-field. The uplift connected with this anticlinal valley, however, continues southward, and affects the strata of the coal-field.

The rocks of the region before us may, for the purposes of our present inquiry, be conveniently considered in four divisions, which are as follows, in ascending order.

I. The ancient crystalline rocks of the Atlantic belt along the southeast side of the Coosa Valley, containing occasional deposits of magnetic iron ore.

II. The various subdivisions between these and the base of the Chazy limestone, included by Smith under the heads of the Ocoee slates and conglomerates, the Chilhowee sandstones, and the rocks of the Knox group, in which latter slates and magnesian limestones

predominate and are associated with great deposits of limonite and of oxide of manganese. These rocks appear in the Coosa and the outlying valleys.

III. The rocks lying between the last and the base of the coal-measures, including representatives of the Chazy and Trenton limestones; the Nashville or Cincinnati group; the succeeding Silurian, represented chiefly by the Clinton group, with its great beds of red hematite or fossil ore; a small thickness of black shale, representing the Devonian; and a considerable mass of strata, chiefly limestones, belonging to the Lower Carboniferous.

IV. The Coal-Measures.

Of the first or crystalline division it is not necessary here to speak, except to say that it consists for the most part, probably, of rocks of Montalban age, as I have shown to be the case in the continuation of the same belt farther to the northeast, in Georgia. Elsewhere, as in North Carolina, they are underlaid by Laurentian gneisses, which there include the magnetites of Roan Mountain. Magnetic and specular ores of iron are, however, found in all the great subdivisions of the Eozoic rocks. A deposit of the former ore is said to be found in Clay County, Alabama.

As regards the second division, which is economically important from the presence of great deposits of brown hematite or hydrous iron-ore (limonite, etc.), as well as manganese-ore—various geological questions arise which can only be mentioned here. The same ore-bearing belt is traced continuously, with constant characters, from the Coosa throughout the Appalachian Valley, and is the Primal and Auroral of Rogers, and the Lower Taconic of Emmons. It is quite distinct from the series called Upper Taconic by the latter, which is the Quebec group of Logan, although the two were for a time confounded. Safford, in Tennessee, gave the name of the Knox group to the older or Lower Taconic series, with which he included some limestones occasionally found in the valley of East Tennessee, containing a fauna which belongs to the horizon of the Calciferous, and thus represents the so-called Quebec group. Professor Smith, following Dana, has, in his classification of the rocks of Alabama, described as belonging to the Quebec group, the whole of the Knox group or Lower Taconic, measuring in East Tennessee, according to Safford, not less than 7000 feet, and consisting of sandstones with shales and limestones, including limonite. The Chilhowee sandstones, and Ocoee shales and conglomerates, which occur chiefly as ridges in the Coosa Valley, and which are, in part, at

least, probably older than the Knox group, and correspond to the lower part of the Primal of Rogers, are by Smith referred to the Acadian and Potsdam epochs of Dana. At the summit of the Knox group, in Alabama, as in Tennessee, is found a fossiliferous limestone with *Maclurea*, marking the Chazy subdivision, to which succeeds the Trenton limestone. Inasmuch as there is reason to conclude, from many observations elsewhere, that there is at this horizon a great stratigraphical break separating the limonite-bearing rocks from those above them, I have placed the Chazy with the Trenton in the third division.

The rocks included in this third division, embrace representatives of all the great groups of Palæozoic rocks from the Chazy to the base of the coal-measures; Ordovian (Lower Silurian or Siluro-Cambrian); Silurian (Upper Silurian); Devonian or Erian; and Lower Carboniferous. The united thickness of all these is, however, very small when compared with that of the same groups farther north in the same great Palæozoic basin. In Pennsylvania, if we take Ashbürner's measured section in Huntington County, we have, from the base of coal-measures to the summit of the Trenton, not less than 17,640 feet, making, with the addition of the latter, more than 18,000 feet. With this measurement, other sections in the same succession in Pennsylvania agree pretty closely. It is unnecessary to recall the fact that this great thickness of rocks consists in large part of sandstones and other coarse mechanical sediments, the foldings of which give rise to the mountainous country separating, in Pennsylvania and Virginia, the coal-measures from the iron-bearing rocks of the great valley and its outliers.

Prominent among the ridges of the Allegheny Mountain region are those of the Oneida sandstone, the first or lowest of these great masses in the intervening series, with a thickness of 2000 feet or more, which forms what is called the North Mountain along the northwest side of the great valley, and is repeated by anticlinal folds farther west. Directly overlying this sandstone is the Clinton or red fossil-ore, which extends continuously from New York to Alabama.

If we now turn from Pennsylvania to Alabama, we find that this great series of strata, which we have included in our third division, is reduced in thickness from 18,000 feet to 1000 or in places 1600 feet, consisting, moreover, in large part of soft and calcareous rocks. As a result of this, the limonites, the fossil-ore, and the coal, instead of being separated from each other by broad belts of mountain-

forming strata, are brought side by side in a comparatively level country, and are thus presented under conditions extraordinarily favorable for mining, manufacturing, and transportation.

The coal-measures themselves, which constitute our fourth division, have suffered no apparent diminution in thickness. They are estimated in round numbers at 3000 feet in Pennsylvania, and are probably not less in Alabama, where one section, hereafter to be noticed, measures, according to Professor Smith, 2600 feet.

The outlying valleys already mentioned are eroded anticlinals, often accompanied with dislocations of the strata, and in them are exposed the fossil-ores and still lower limonites. The Long Valley, which extends from below Tuscaloosa by Birmingham northward, and in its lower and middle portions is known as Roup's and Jones's valleys respectively, divides, as we have seen, the Warrior coal-field from the Cahaba outlier on the east, the distance between the two coal-fields being rarely over six or eight miles. In the upper part of the course of this anticlinal uplift, the strata of the third division are seen dipping regularly beneath the coal-measures on each side; but toward the southwest, the beds have been sharply folded and pushed over to the northwest side, producing a real inversion, so that all the strata appear dipping to the southeast. The Lower Carboniferous limestones on the western side of the valley thus lie below the Chazy and Trenton limestones, and these again below the still older rocks of the Knox group, the whole series being overturned and folded upon itself. The structure is further complicated in parts by faults, bringing up, on the east side, the older rocks against the Lower Carboniferous limestones.

As a consequence of these accidents, so well described by Professor Smith, some of the beds are in part concealed, and others are duplicated. Conspicuous among these are cherty ridges belonging to the second division and associated with the limonites. Still more marked are the rocks of the Clinton group, known in Tennessee as the Dyestone and in Alabama as the Red Mountain group, from the beds of red hematite or fossil-ore seen everywhere along its outcrop.

A remarkable dislocation of the strata occurs to the southeast of the Cahaba field, where white limestones of the Knox or Taconic series are brought, by a great upthrow, on a level with the highest of the coal-measures, here sharply cut off and upturned. This great fault was estimated by Rothwell at not less than 10,000 feet, and his interpretation of the structure, though questioned at the time,

has since been confirmed by the observations of Professor Smith and myself.

The eroded valley which divides the Cahaba from the Warrior field is bordered on each side by a rim of the basal sandstones of the coal-measures, the tilted edges of which are still higher than the undisturbed beds of the coal-fields on each side. The result of this is the singular one that the waters of the valley break through the ridges on each side, and find their way into the Cahaba and Warrior Rivers, the valley being really higher than the plains on each side of it. As a consequence of this peculiar drainage, we find that the limonite ores along the valley, instead of being buried in clay, as elsewhere is usually the case, are often laid bare, and form hillocks and ridges scarcely covered with soil.

The Warrior coal-field is divided by Smith into the plateau or table-land region on the north and the Warrior basin proper lying to the south. The southward extension of the anticlinal which in its eroded portion farther north gives rise to Brown's Valley, traverses the field as a low ridge, and divides the basin into two unequal troughs. Of these, the one to the eastward—which is the narrower, and is drained by the Locust Fork or Little Warrior River—is the best known, lying as it does between the anticlinal just mentioned and that of Long Valley. A section between this valley and Locust Fork, described in detail by Professor Smith in his report for 1877–78, shows above the Lower Carboniferous limestone about 2600 feet of coal-measures, including a conglomerate at the base. This, from its proximity to the valley and to the railroad, is the part of the field which has been best explored. There are found in this section twelve seams of coal of from two and a half to seven feet, and having an aggregate thickness of fifty feet. Of these, five seams have been mined. The strata are nearly horizontal and affected only by slight undulations. The Pratt seam,—the highest in the section,—which is now extensively mined about six miles west from Birmingham, yields four and a half feet of coal, with one shale parting. As worked at the time of my visit in February, 1882, from two slopes and a shaft of 250 feet deep, it was yielding from 1200 to 1500 tons of coal daily, a considerable portion of which was coked at the mine. According to more recently published statements, the production at the Pratt mine has since been much increased. Several other productive mines are opened in adjacent parts of the same field.

To the west of the division just described, the development of coal in the region drained by the Big Warrior River is not less

considerable, the later surveys of Smith and others showing the existence of many excellent seams of good quality, measuring from three to six feet in thickness.

In its southern part, where the Cahaba field attains its maximum breadth of twelve miles, the measures are regular, and have a dip of from six to ten degrees along the western border, gradually increasing to twelve or fifteen degrees near Lily Shoals, on the river, and to forty-five degrees or more near to its eastern edge, where the strata along the great fault are sometimes nearly vertical. Farther northward, about thirty miles from its southern extremity, where the Cahaba field is reduced to a breadth of six miles, the strata are somewhat crushed, and the upper measures, which appear farther south, near Monte Vallo, are wanting. The field is here crossed obliquely by the Alabama North and South Railroad, along the line of which, according to Rothwell, are found nine workable beds of coal, measuring from two to four feet in thickness, and giving an aggregate of over twenty-eight feet. In the wider and less disturbed parts of the field, farther south, the coal-seams are thicker. On Four-Mile Creek, the same observer found eight seams with an aggregate thickness of thirty-eight feet, besides four higher seams in the Monte Vallo beds, equal to twelve feet. Along the eastern border of the field, however, the lower coals will be too deep for profitable mining.

Besides the analyses of coals from this field given by Rothwell, an extended table of analyses of others from the Warrior basin is given by Smith in his report for 1879–1880, and it may be said, in general terms, that the coals from both these fields are equal to those from the more northern portions of the Appalachian basin. They present the usual varieties in quality and composition, some of them being dry-burning coals, others coking coals with as much as 65 per cent. of fixed carbon, while others contain much more volatile matter.

The iron-ores of the region, as already mentioned, belong to two classes, the red hematite or so-called fossil-ore of the Clinton beds, and the brown hematite below them. The former is almost everywhere in its place at the outcrop of the rocks of the third division throughout the Long Valley. The ore has been traced, according to Professor Smith, with very little interruption, from Pratt's Ferry, on the Cahaba above Centerville, nearly to the Georgia line, sometimes very pure, and at other times too siliceous for use. Near Birmingham, where it is mined for the Oxmoor furnace, there are seen in a thickness of thirty feet twenty-two feet of ore, with interposed shaly

bands. Numerous analyses of the ore mined at different points in the valley, where their thickness is from ten to twenty feet, give from 42 to 55 per cent. of iron. They are generally smelted with an admixture of the brown hematite of the region.

As regards the brown hematites, I can only say, after comparing them with similar deposits of these ores from Massachusetts southward to Virginia along the Great Valley, that they are of wonderful extent and richness, and, so far as my observations go, in these respects unsurpassed. These hydrous ores have been generated, as has been shown by myself and others, by the alteration *in situ* of interstratified masses and layers, in some cases of carbonate of iron and in others of pyrites, included in the more or less argillaceous strata now changed to clays.* As already explained, the washing-away of a great portion of these clays, where they are exposed along the lines of uplift, has left behind a correspondingly large amount of their included ore. From this, it results that over many square miles along the outcrop of these lower rocks, both on the west and east sides of the Cahaba coal-field, we find a succession of hillocks composed in great part of masses or fragments of brown hematite; while in their vicinity, excavations show the same ore still imbedded in the stratified and often highly inclined clayey beds resulting from the decay of the original rocks. In some cases, the same ore, of unusual purity, is found imbedded in large irregular masses in a cherty or quartzose rock which belongs to the same geological series as the slates. It appears, from numerous analyses of these ores, that they are sometimes less hydrated than limonite and approach to turgite in composition. They have long been mined and smelted with charcoal along the Coosa Valley, where they are not less extensively developed than in the outlying valley west of the Cahaba field, in which district they are now mined for the furnaces of Birmingham and its vicinity.

It would be foreign to my present plan to enter into details as to any particular portion of the region before us. Its value as a whole consists in the fact that it possesses coal abundant in quantity, excellent in quality, and situated in proximity to the waters of the Gulf of Mexico, with which it can be readily connected by improvements of the rivers draining the coal-fields. From Tuscaloosa, which is on the southeastern edge of the Warrior field, there is navigation throughout the year to Mobile, a distance of 355 miles.

* Second Geological Survey of Pennsylvania, Report E, Azoic Rocks, pp. 202-204.

As appears from a report of U. S. Engineers to the War Department, submitted to Congress in 1880, there is between Tuscaloosa and Sipsey Fork, in the Warrior basin, in a distance of $92\frac{1}{2}$ miles, a rise of about 160 feet. A system of dams and locks, with chambers 145 × 30 feet, would suffice to establish water-communication from this point, in the heart of the coal-field, to Mobile throughout the year, for an estimated cost of $400,000. Barges laden with cotton, coal, and lumber have, it is said, for many years been sent down this way during seasons of high water.

The Alabama River is navigable from Montgomery or Wetumpka to Mobile, and the Cahaba River, which drains the Cahaba field and falls into the Alabama a little above Selma, can in like manner, according to official report, be made navigable at a cost of $500,000.

The present lines of railroad have done little for the development of this mineral region. Two great north and south lines, as already pointed out, the Alabama Great Southern Railroad and the Selma, Rome, and Dalton Railroad, pass down the valleys west and east of the Cahaba field. The South and North Alabama Railroad, however, a continuation of the Louisville and Nashville Railroad, which in its course from Decatur to Montgomery intersects the first of these roads at Birmingham, and the second at Calera, crosses a small part of the Warrior field near Birmingham, and also the narrow portion of the Cahaba field. The Georgia Pacific from Atlanta, passing through Birmingham, will traverse the breadth of the Warrior field. During the last years of the civil war, a line was surveyed and in part graded for the purpose of opening the lower part of the Cahaba field, starting from Ashby, a little below Calera, and running northwest and then northeast into the heart of the coal-field. It has lately been proposed to complete this work, and other projects are under consideration for the development of the Cahaba field, where very little has been done since the close of the war, during which coal was here extensively mined. My own observations at the old openings satisfied me of the correctness of Rothwell's observations, and showed that we have in this field a region which, as regards the supply of coal, the proximity of iron-ore, and facilities for mining, smelting, and transportation, is unsurpassed.

As regards the iron-resources of the region, we may note, in the first place, the proximity of the ore to the coal. With the limited exception of deposits of ore in the coal-measures in the northwestern portions of the great Ohio basin, it is well known that the ore and coal in the United States are generally widely separated. Not to

speak of the crystalline ores of the older rocks, the great supplies of limonite upon which the iron-smelting industry of Pennsylvania and Virginia is largely based, present similar conditions. It suffices to look at a geological map of these States to see what a broad belt of mountainous country separates the limonite-bearing rocks of the Great Valley from the coal-measures, while a very considerable interval also divides these from the fossil-ores. Owing, as already explained, to the thinning-out of the intervening rocks, which are reduced to less than one-tenth of their thickness, and to the fact that those that persist are, for the most part, soft and crumbling, we have seen how the ores and coal, so widely separated elsewhere, are, in Alabama, brought into close proximity. Thus, in Long Valley, a distance of six or eight miles only separates the coal-fields from each other, while abundant deposits both of the red and the brown hematites are found in the interval between them. It is not therefore surprising that this valley is rapidly becoming an important centre of iron-production, where coke-made iron can be produced more cheaply than anywhere else on this continent.

The remarkable dislocation and upthrow, already noticed as occurring on the southeast side of the Cahaba field, brings about a still closer approximation of iron-producing materials by lifting up the lower ore-bearing rocks side by side with the coal-measures. Here, on the banks of the Cahaba River, deposits of limonite of great abundance and purity are found extending over many hundreds of acres of the surface, within two miles of opened beds of coking coal, while cliffs of a pure white limestone, well fitted for flux, are seen within the same distance. It is impossible to look upon all the developments of coal and rich iron-ores, elsewhere so widely separated and here brought into close proximity, without feeling that these Alabama coal-fields are destined at no distant time to be the seat of an immense mining and manufacturing industry.

It is true that this region is now somewhat removed from our great centres of population and consumption; but with the improvements in water-transportation now projected, iron could be carried to Mobile, and thence by sea to American and foreign ports, more easily than from any other iron-producing region in the Union. Nor should we forget in this connection what a vast future awaits the South with its newly awakened activity in agriculture and in manufacturing industries; a region offering such advantages of soil and climate as cannot fail in the next few years to attract a very large immigration. If we look to the census-returns of 1880, we shall find that the eight

coastal Southern States, from North Carolina to Texas, with a population of about nine and a quarter millions, showed an increase over that of 1870 of 41.6 per cent.; while the increase for the Union, taken as a whole, was but little over 30 per cent. To Alabama, as the great coal and iron-producing State of the South, the chief part of this vast region may be made to a large extent tributary.

Already in 1875, the great natural advantages of Alabama for the manufacture of iron attracted the attention of Isaac Lowthian Bell, who, in a communication to the British Iron and Steel Institute, declared that the region "presents advantageous conditions for the economical production of the metal rarely met with even in Great Britain;" elsewhere asserting that it would "prove a match for any part of the world in the production of cheap iron." Not less striking is the language of Abram S. Hewitt, who says of Alabama: "It is the only place upon the North American continent where it is possible to make iron in competition with the cheap iron of England, as measured not by the wages paid, but by the number of days' labor which enter into its production. The cheapest place on the globe until now for the manufacture of iron is the Cleveland district, in Yorkshire, England. The distance of the coal and iron from the furnaces there averages about twenty miles. Now, in Alabama, the coal and the ore are in many places within half a mile of each other. This region, so exhaustless in supplies, so admirably furnished with coal, so conveniently communicating with the gulf, will be of infinitely more consequence to us for its iron than it has ever been for its cotton. The ore is the foundation of an industry and a prosperity which no curse of slavery, nor rebellion, nor interference with economic laws can ever overturn. I think this will be a region of coke-made iron on a scale grander than has ever been witnessed on the habitable globe."

I have sought on this occasion to call the attention of the members of the Institute of Mining Engineers to some of the more remarkable points in the geology of the coal-region of Central Alabama, especially as compared with that of the more northern portions of the same great coal-basin, and to show the intimate and peculiar relations both of the geology and the geography of the region to its economic interests. I have also wished to record the strong impressions made upon me by what I saw there during a late visit of a week. The development in Central Alabama, not only of a great coal-trade, but of a vast iron-industry, is certain in the near future, and indeed has already begun. I leave for another time and

place the discussion of details respecting the region. Meanwhile, it must be said that the geographical position of Alabama, its mineral wealth, its fertile soil, and its favorable climate are destined to give it a pre-eminent place among the Southern States of our Union.

THE MANAGEMENT OF STRUCTURAL STEEL.

BY ALBERT F. HILL, C. E., NEW YORK CITY.

THE manufacture of structural shapes in steel of uniform quality, which shall command the full confidence of the engineer, is a problem in practical metallurgy which is beginning to attract much attention in this country. The progress of the past few years in the improvement of plant and processes has placed it within the power of the steel-maker to supply a material of such chemical composition as will meet the requirements; but this solves only in part the difficulties of the constructor. It is well understood that the influence of shop manipulations is a most decisive one upon the mechanical properties of the finished product; in many cases so great, in fact, as to cause an entire transformation in the character of the material, and to render it unfit for the service for which it was intended. On the other hand, mechanical treatment is frequently resorted to as an efficient corrective of certain undesirable properties, which may be due either to chemical composition or previous manipulation. This understood and accepted, it is evident that careful investigation of the effects of mechanical treatment is fully as necessary to the successful use of steel in engineering structures, as the investigation of the influence exerted by its chemical composition.

All structural material has to undergo more or less mechanical treatment, such as shearing, punching, upsetting, etc. Each of these operations produces effects which are far more marked and decisive in steel than they are in iron, and means must therefore be adopted to counteract, or at least to modify, these effects before the material is permitted to enter the structure.

The fact that both shearing and punching affect the tenacity and elasticity of steel has long been recognized; but, through more recent investigations, it has been established that these effects are purely local, and are therefore susceptible of correction by other and simpler means than annealing. The importance of this discovery to the use of steel in structures is very great. The impracticability of

making use of annealing in riveted girder work, for instance, is too evident to need discussion; while, on the other hand, to resort to drilling, so as to avoid the bad effects of punching, renders the work too costly.

As is well known, both punching and shearing produce hardening effects upon steel. These effects, however, extend over but a limited area in the immediate vicinity of the points where the operation takes place. Thus Lieutenant Barba, in his experiments with Terre Noire and Creuzot steels, reached the conclusions:

1. That the effects of punching and shearing are essentially local, and spread over only a very restricted region—less than .04 inch on the edges of the punched or sheared parts in plates less than .5 inch thick.

2. That annealing will correct the alterations caused by shearing or punching; and

3. That the removal of about .04 inch of the metal from the punched or sheared edge will destroy the effects of punching or shearing, and bring the metal back to the state it would be in if drilling or planing had been resorted to in the first place.

Experiments made upon steel plates, the analyses of which were known to me, and some of the results of which will be found in tabulated form at the end of this paper, have led me to believe that Lieutenant Barba's conclusions, while unquestionably correct in general principle, are susceptible of modification. Especially is this true of the assertion that "the removal of about .04 inch of the metal from the punched or sheared edge . . . . . will bring the metal back to the state it would be in if drilling or planing had been resorted to in the first place."

From a series of about two hundred tests, made with a view to find out exactly how much metal would have to be removed around the edge of punched holes; or, in other words, what enlargement by reaming would be necessary to eradicate the effects of punching, I have come to the conclusion that the amount of metal to be removed, if it is to restore the material, is not a fixed quantity, but varies with the chemical composition of the steel and the thickness of the plate. The field covered by these tests comprised steels of three distinct carbon percentages, and from each of these plates three different thicknesses were rolled. In the choice of carbon percentages for these tests I was guided by the idea that it was of greater importance to investigate the more highly carburized steels—the upper limits, as it were, of structural steels—rather than the lower ones, since

there was no question in my mind that Lieutenant Barba's experiments were made upon low steels, and for such his conclusions undoubtedly hold good. In the choice of thickness of plates I was governed by the desire to investigate primarily such web thicknesses as are likely to be of most common occurrence in riveted steelwork. Therefore, as will be seen in Table I, we have $\frac{1}{4}$-inch, $\frac{3}{8}$-inch, and $\frac{1}{2}$-inch plates of .30 C., and the same three thicknesses in .40 C. and also .50 C. open-hearth steel plates. The plates were throughout eighteen inches in width, and all the specimens were cut out in the planer, crosswise to the direction of rolling. This was done simply on account of greater convenience in handling; and, so long as they were all tested in the same direction, the direction of the rolling could have no influence on the comparison of the results. The first tests in each case were made upon three pieces, one taken from about the middle and the two others from the ends of the plate. The average strength thus obtained was accepted as the strength of the original plate. These averages, as well as the average elongations, will be found in the first two columns of Table I. The remaining parts were then cut up into similar strips, and a $\frac{3}{4}$-inch hole punched in the centre of each strip. Five specimens thus prepared were tested in each carbon and in each thickness of plate. The results of these tests will be found in the next two columns of Table I, and an inspection of them shows that the lower carbons are comparatively more injuriously affected by punching than the higher ones, and the heavier plates more than the lighter ones.

The next forty-five specimens (again five of each carbon and of each thickness of plate) had the diameter of the holes enlarged by reaming .04 inch. The fifth and sixth columns of the table show the results obtained by testing this series. As will be seen, the enlargement by .04 inch effected the restoration only of the $\frac{1}{4}$-inch and $\frac{3}{8}$-inch plates in the .30 C., and that of the $\frac{1}{4}$-inch plates in the .40 C. The next enlargement increased the diameter of the holes by careful reaming .06 inch. We find now the $\frac{1}{2}$-inch plate in the .30 C., the $\frac{3}{8}$-inch plate in the .40 C., and the $\frac{1}{4}$-inch plate in the .50 C. restored. The enlargement of the diameter of the holes .08 inch restores next the $\frac{1}{2}$-inch .40 C. and the $\frac{3}{8}$-inch .50 C. plates; while the $\frac{1}{2}$-inch .50 C. plates, as is shown, required an enlargement of fully .1 inch.

While it is not claimed that these tests furnish conclusive data as to the requisite amount of metal to be removed in all cases, they certainly seem to be a very clear indication of the direction which must be given to the line of investigation in this field of constructive

designing. The results given must, however, be accepted as conclusive evidence of the restoration of strength effected by the enlargement of the holes by reaming, and that the enlargement requisite for this purpose varies with both thickness of plate and carbon percentage. The bad effects of punching and shearing are due to the intense local pressure produced by the punch or the shears, which causes a solution of the mechanically mixed carbon, and effects a real tempering of the parts subjected to these operations, and this causes the marked increase in hardness of the parts affected. That this explanation of the effects of punching, shearing, and hammering is the true one, is evidenced by the fact that proper annealing will destroy these effects and restore the material to its original condition.

Table II contains a series of tests on the annealing effects in sheared and cold-hammered O. H. steel plates. Size of specimens, $\frac{3}{8} \times 2 \times 18$ inch, leaving twelve inches clear between the jaws of the testing machine. In these experiments the specimens which had to undergo annealing were heated simultaneously in a gas furnace, and annealed in lime for about fifteen hours. As will be seen, the restoration of the metal is in every case almost complete, the differences in elastic limit and elongation between the original plates and the annealed ones being practically not appreciable, while the differences between the original and the sheared or punched plates is very considerable.

The next manipulation for which I shall ask your consideration is welding. One of the most serious obstacles that confronts us in the adoption of steel for purposes of bridge and other construction is the distrust of its welding capacity. That this distrust is founded far more upon prejudice than upon fact is becoming more and more apparent with a clearer conception of the difference in the methods of working iron and steel. Again, the "carbon line." becomes our guide, and we soon find that the weldability of steel is in inverse ratio to the carbon percentage—that is, the facility with which steel may be welded to steel diminishes as the metal approximates to cast-iron with respect to the proportion of carbon; or, what is equivalent, it increases as the metal approximates to wrought-iron with respect to the absence of carbon. Nevertheless, steels far in excess in carbon percentage of any that can ever be used in construction, have been successfully welded by proper treatment.

It will, probably, be remembered by many present that, at the Philadelphia Exhibition, the Swedish Sandvik Company showed a series of steels, ranging from .60 C. to 1.10 C., which had been suc-

cessfully welded. These steels were of the ordinary quality used at the works, and the welded pieces, being polished at the place of welding, showed in every case that the union was perfect. From a paper read before the Liverpool meeting of the Iron and Steel Institute in 1879, by Mr. Ratliffe, of the Mersey Steel and Iron Works, I learn that he has succeeded in welding mild Bessemer steel forgings without any flux, in the same way as ordinary iron. This metal before welding contained by analysis:

Carbon	0.153
Phosphorus	0.089
Silicon	0.026
Manganese	0.785

To prove the soundness of the weld, a piece of the bar $3\frac{1}{2}$ inches diameter was tested under a 5-ton hammer, and only broke with the twenty-ninth blow, showing no weakness where the welding had taken place.

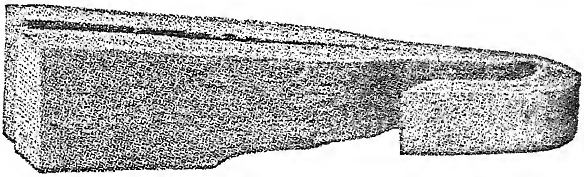
In a series of experiments made quite recently by myself upon die-forged eyebars, I used O. H. steel of the following composition:

Ingot.	1st analysis.
Carbon	0.30
Manganese	0.63
Phosphorus	0.033
Silicon	trace.
Sulphur	...
Bar.	**2d analysis.**
Carbon	0.32
Manganese	0.60
Phosphorus	0.034
Silicon	0.02
Sulphur	0.045

The heads of these bars were formed by the addition of two pile-pieces for each head to the original bar. As the experiments with these bars were to serve also the purpose of a different demonstration, I shall revert to them later on. Meanwhile I desire to call your attention to one of the welding tests to which these bars were subjected. The piece here shown (represented in Fig. 1) was formed from two bar ends. The parts not brought under the hammer are seen cleft open, while the welded portion is drawn out into a $\frac{3}{4}$-inch square bar. After welding, the whole piece was heated to a dark

cherry-red and dipped in oil, where it was allowed to cool. This welded portion was next bent double while cold, and the whole cut in two, longitudinally, in the planer. The cut surface was polished, and did not show any imperfection in the welding; this surface was

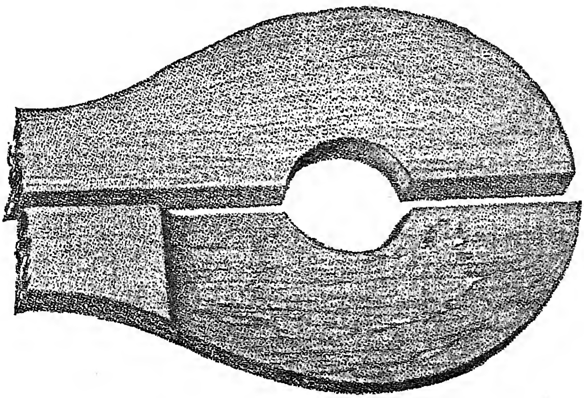
FIG. 1.



subsequently treated with acid, and this also failed to develop any weakness, as can be seen. There can certainly be no question as to the perfection of the weld.

Fig. 2 represents cut and polished sections of one of the eyebar heads after fracture. As is seen, the head was first cut in two, longitudinally, and the polished surface of this cut not showing any

FIG. 2.



trace of weakness, although taken through the elongated pinhole, the other half of the head was planed down to about half its thickness, where by acid treatment the line of weakness shown in the illustration was developed. It must be remembered, however, that this result was obtained only subsequent to the breaking of the bar; that lines of weakness must have been developed throughout the whole bar while being strained to rupture; and that, since the bar

broke in the shank, the weld had proved itself stronger than the bar. Fig. 3 is a portion of the shank near the break, and shows well the reduction of area and silkiness of fracture.

To prevent decarburization and to render the welding places perfectly clean, various welding powders have been recommended, but have never come largely into use—for, after all, a good and clean weld, be it in iron or steel, depends upon the skill and the intelligence of the blacksmith. Unfortunately that dignitary is only too often dogmatic and obstinate, "knows all about steel," and, therefore, cannot be taught anything. If the steel maker has furnished

Fig. 3.

the constructing engineer with otherwise good steel, but which, somehow or other, "will not weld," the source of the trouble may safely be sought for in the blacksmith shop.

There is one point in welding steel which cannot be too strongly insisted upon, and that is that the pieces, after having been brought to the welding point, should not be struck heavily with the hammer, but only tapped lightly at first until they have begun to weld; after that the sledge or steam hammer may be used with perfect freedom. Another important consideration in welding steel is the heat. While it is impossible to give any specific rules on this point, the general rule, which will be found to hold good in all cases, is not to heat the steel any higher than is absolutely necessary to effect a weld—the higher the steel is in carbon, the lower the heat at which it ought to be worked; hence necessitating heavier hammers—and next, not to finish the operation at too low a temperature. It will be best to work the steel as rapidly as possible, reheat as often as required to prevent working or finishing cold, and anneal the whole piece

immediately after welding, not only the immediate vicinity containing a weld. The annealing heat should always be higher than that at which the piece was finished.

In the manufacture of eyebars the hydraulic upsetting process will, without doubt, be found to give the best results in steel, as it does in iron, yet I have no hesitation in saying that the eyes may be formed by welding, if done by experienced hands who really understand the heating and treatment of steel, without any greater risk of imperfect welds than there is in iron. The danger from welding is no greater in steel than in iron, and the source of danger the same in both, namely, bad workmanship.

But of all the shop manipulations required in the management of structural steels, annealing is, without question, the one of the most importance to the engineer. Its corrective effects, in cases of local hardening, occasioned by previous working of the material, are at present fully acknowledged and understood. But while there is no doubt of the beneficial results obtainable from careful annealing, it must be conceded, on the other hand, that this treatment is liable to do more mischief than good, unless properly performed. Great care must be exercised in the heating, in order to prevent oxidation or partial decarburization. It ought, whenever possible, to be performed in a gas furnace and at a temperature higher than that at which the metal was last worked. The scarcity of recorded experiments on the effects of annealing at various temperatures, more or less rapidly applied, and under different conditions of cooling, has led me to undertake a series of tests of this nature.

It was deemed desirable to establish, in the first place, whether or not the annealing produced different effects upon steels of different carbon percentages under equal conditions of heating and cooling. For this purpose, specimens exactly alike in dimensions, but differing in carbon percentage, were heated slowly and simultaneously in a gas furnace to a dark cherry-red, and then annealed in lime for 12 hours. The average results obtained from these tests are collected in Table III. From the result obtained there, it will be seen that the effect of the same heat is greater in the lower carbons than in the higher ones, and that, therefore, if we desire to accomplish by annealing the same results in these latter, we shall have to apply a heat which will be found dangerously near to the point where slow cooling is apt to be followed by crystallization. To avoid this danger, it will be found preferable practice, when working in the higher carbons, to resort to repeated annealings at lower temperatures.

In endeavoring to collect opinions on this subject of proper annealing heats from those whose practice required them to resort to annealing, I encountered the most divergent views. Different manufacturers who used steel from the same mills and of the same grade and for the same purposes, differed very decidedly as to the proper heat required to produce the desired effect, this difference of opinion covering the whole range from black heat up to bright cherry.

I next proceeded to make experiments upon the same grade of steel at different temperatures. These results will be found in Table IV, and show very plainly that in steel the loss of tensile strength and gain in stretch are in direct ratio to the heat applied—that is, in annealing at the lower heat, the loss of strength and gain in ductility are less than at higher temperatures.

The difficulty of constructing a furnace suitable for annealing long tension members led me to try the experiment of annealing in molten lead. Notwithstanding the fact that it is frequently asserted that good results may be obtained from this, I have invariably found the effects from this metal bath to be exceedingly unsatisfactory, and I do not see at present any other solution for this difficulty than the construction of specially designed annealing furnaces. I further found that many of the unfavorable results of annealing could be directly traced to the method of cooling and to the want of proper exclusion of the air. This led me to resort to annealing in oil, and the results of a few of the tests made by this mode of annealing are given in Table V. As is seen there, the results obtained in this way are by far the most satisfactory and the least variable.

These tests were all made on small specimens, and in order to find out if the conclusions reached in this way would be borne out in full-size bridge members, I had some eyebars made and tested at the Watertown Arsenal.

I have already referred to these bars and given their analyses, and will only repeat here, in short, that they were of .30 carbon steel, with built-up heads and die-forged. The results of these tests are found in Table VI.

The steel for these bars was made at the Otis Steel Works, of Cleveland, Ohio, and the eyebars were made under my personal supervision at the Passaic Rolling Mill Co.'s works, of Paterson, N. J. They were the first steel eyebars ever made there, and of course a certain amount of difficulties, on account of the novelty of the work, might well have been expected. The bars were too light for hy-

draulic upsetting, and had therefore to be upset by hand and heated in an ordinary blacksmith's fire, requiring at each end from three to four heats. Next, the building up of the heads with two pieces required as many more heats. It will therefore be readily seen that the steel received rather severe treatment, and considering that the finishing of each head required from seven to eight heats, an error of judgment in any one of which might have ruined the material or resulted in a weak weld, the results obtained must certainly be regarded as very satisfactory, and as exceedingly creditable to the intelligence of the men engaged in the work.

After finishing the heads the bars were heated once more in an ordinary furnace, and the first four, marked A, B, C, D, were then annealed for about 12 hours in hot ashes, and the bars E and F by immersion in oil. To find out, further, if a second annealing, if done in oil, would still show an improvement by this method over the ordinary mode of annealing, the bars C and D were, after cooling in the ashes, once more reheated and then annealed in oil. Summarizing the results of the tests, we find:

1. That in every case the bars broke in the shanks, developing no weakness in the welds, and that, therefore, the welding had been successfully accomplished, and

2. That the difference between annealing in oil and annealing in the air is largely in favor of the former.

I am not prepared to accept these results as quite conclusive, yet am strongly impressed with the idea that annealing in oil, or, as perhaps some will be inclined to call it, "tempering in oil," can be very successfully employed with the tension members of steel structures.

It only remains now to call attention to the effects of certain mill manipulations, which are also apt to have a pronounced effect upon the mechanical properties of the final product. Foremost among these is the rolling, and the heat at which this operation is commenced and finished. Overheating or underheating, too hot finishing or too cold finishing, excessive reduction in the passes, or too little reduction from the ingot, have all their peculiar influence and are capable of producing such changes in the steel as to render nugatory the forecast of the mechanical properties based upon its chemical analysis.

Engineers will find that the character of the rolling-mill machinery determines very largely the heating practice in different

mills. In mills with abundance of power, strong trains and proper reductions in the passes, it will be found that overheating is rare, but, on the other hand, in order to save reheating, and with full reliance in the power of the train, finishing is frequently done at too low a heat, and roll-hardening is the result. Again, in mills with weak trains, inadequate power, or excessive reduction for speed of rolling, it will be found that high heating is the rule, and carried to the very verge of safety, and hence burnt steel is not infrequent. Roll-hardened steel is easily remedied by annealing, but the heat must be uniformly applied over the whole piece at once, and carried to a bright red—dark red is insufficient in this case—and the cooling must be done very slowly and under exclusion of the air. Burnt steel is best remedied by consignment to the scrap-heap.

Another source of danger to the homogeneity of the finished product is to be found in cold-straightening. The presses in many mills are so constructed as to exert absolute shearing stresses, and are apt to do more harm than any subsequent service can do. Cold-straightening ought to be done at a black heat, and the local effects of the press be modified by distribution over a large area. This can be accomplished by the use of broad oak wedges or the insertion of pieces of plank. Generally plates, angles, beams, etc., have of necessity to undergo more or less hammering in the course of construction, and as this produces effects comparable to punching and shearing, though in a much less degree, it becomes necessary, in steel construction, to modify these effects in the same way by protecting the metal surface with wood and substituting heavy wooden mallets for sledges.

In fine, the working of steel in every stage requires care, and, above all, intelligence, and the men engaged in it must be impressed with the necessity for careful manipulation and rational treatment. Undoubtedly the steel must possess the proper qualities for structural purposes in the first place, but then it must also be properly treated subsequently if it is to bring those qualities into the finished structure.

TABLE I.—COMPARATIVE TESTS OF THE EFFECTS OF ENLARGING PUNCHED HOLES BY REAMING IN STEEL PLATES OF VARIOUS CARBON PERCENTAGES AND THICKNESSES.

Carbon per cent.	Dimensions of test pieces.	Orig. plate. Average. Ultm. tensile strength in lbs. per sq. in.	Orig. plate. Average. Elongation per cent.	Plate with punched hole .75 in. diam. Ultm. tensile strength of effect. sec. in lbs. per sq. in.	Plate with punched hole .75 in. diam. Elongation. Per cent.	Punched hole .75 in. dia., reamed to .79 in. dia. Ultm. tensile strength of effect. sec. in lbs. per sq. in.	Punched hole .75 in. dia., reamed to .79 in. dia. Elongation. Per cent.	Punched hole .75 in. dia., reamed to .81 in. dia. Ultm. tensile strength of effect. sec. in lbs. per sq. in.	Punched hole .75 in. dia., reamed to .81 in. dia. Elongation. Per cent.	Punched hole .75 in. dia., reamed to .83 in. dia. Ultm. tensile strength of effect. sec. in lbs. per sq. in.	Punched hole .75 in. dia., reamed to .83 in. dia. Elongation. Per cent.	Punched hole .75 in. dia., reamed to .85 in. dia. Ultm. tensile strength of effect. sec. in lbs. per sq. in.	Punched hole .75 in. dia., reamed to .85 in. dia. Elongation. Per cent.
	¼″	79,200	20.2	62,400	5.6	80,600	19.0	......	......	......	......	......	......
.30	⅜″ x 2″ x 18″	83,300	19.0	60,800	5.0	85,000	17.9	......	......	......	......	......	......
	½″	88,400	17.3	59,100	4.7	83,200	11.2	88,900	16.0	......	......	......	......
	¼″	82,900	18.5	66,100	5.1	84,100	18.6	......	......	......	......	......	......
.40	⅜″ x 2″ x 18″	86,500	15.9	64,800	4.9	79,300	11.3	87,200	13.0	......	......	......	......
	½″	89,800	13.0	61,300	4.0	65,100	4.3	77,400	6.6	90,300	11.7	......	......
	¼″	83,700	14.7	74,900	5.4	76,100	5.3	83,900	13.9	......	......	......	......
.50	⅜″ x 2″ x 18″	88,500	13 1	71,200	3.0	74,100	4.1	79,900	8.7	88,800	11.9	......	......
	½″	91,800	11.4	69,300	2.5	70,900	2.0	73,700	3.0	81,400	4.7	92,300	10.0

TABLE II.—ANNEALING EFFECTS ON SHEARED AND HAMMERED O. H. STEEL PLATES.

Carbon per cent.	Treatment of test pieces.	Average tensile resistance of 5 test pieces in pounds per sq. in. of section at Elastic Limit.	Average tensile resistance of 5 test pieces in pounds per sq. in. of section at Rupture.	Per cent. elongation.
.30	Specimens cut in planer........................	45,170	86,720	19 1
.30	Specimens sheared out........................	31,290	69,376	11.3
.30	Specimens sheared out and annealed...	44,830	84,950	20.2
.30	Specimens hammered cold, then cut out in planer.:................................	63,720	85,380	3.4
.30	Specimens as above and annealed.........	46,360	82,970	16.8
.40	Cut in planer..	53,640	89,880	16.4
.40	Sheared out	41,250	75,400	8.3
.40	Sheared out and annealed	51,470	86,320	16.7
.40	Hammered cold, then cut out in planer	64,180	87,560	2.3
.40	Hammered, anneal'd, then cut in planer	51,710	85,890	14.1
.50	Cut in planer..	62,070	93,210	11.4
.50	Sheared out..	49,960	82,930	5.2
.50	Sheared out and annealed....................	59,390	92,560	12.0
.50	Hammered, then cut in planer	71,630	91,810	0.7
.50	Hammered cold, then annealed and cut in planer..	65,120	90,620	8.1

TABLE III.—COMPARATIVE RESULTS OF ANNEALING EFFECTS UNDER UNIFORM HEATS UPON STEEL OF DIFFERENT CARBON PERCENTAGES.

Carbon per cent.	Dimensions.	Average tensile resistance of 5 test-pieces in lbs. per sq. in. at		Average elongation in 12 in., per cent.	Average tensile resistance of 5 test-pieces in lbs. per sq. in. at		Average elongation in 12 in., per cent.	Remarks.
		Elas. Lim.	Rupture.		Elas. Lim.	Rupture.		
		Unannealed.			Annealed.			
.30	1½″ x ½″ x 12″.	43,100	76,400	24	....	....	....	Fractures fine and silky throughout.
		....	....	....	32,300	59,200	29	
.40		49,300	90,900	17	....	....	....	Fracture as above.
		....	....	....	41,700	79,500	22	
.50		56,700	97,200	13	....	....	....	Fracture very good.
		....	....	....	48,800	90,700	16	

TABLE IV.—COMPARATIVE RESULTS OF ANNEALING EFFECTS AT DIFFERENT TEMPERATURES UPON STEEL OF UNIFORM COMPOSITION.

Carbon. per cent.	Test.	Cold.	At black heat.	At dark cherry red.	At bright cherry red.	Remarks.
.30	Elastic limit per square inch ...	43,320	40,800	35,560	30,920	Averages of four pieces at each temperature.
	Ultimate per square inch.........	74,950	70,360	62,890	57,380	
	Per cent. elongation in one foot	20.	23.	28.	36.	
	Reduction of area, per cent......	35.	38.	44.	53.	

TABLE V.—COMPARATIVE RESULTS OBTAINED BY ANNEALING IN LIME AND IN OIL, STEEL OF UNIFORM COMPOSITION AND HEATED TO THE SAME TEMPERATURE.

Carbon per cent.	Test.	Cold.	Heated to dark Cherry.		Heated to bright Cherry.		Remarks.
			Annealed in Lime.	Annealed in Oil.	Annealed in Lime.	Annealed in Oil.	
.40	Elastic limit per square inch	50,180	41,930	45,470	36,660	40,190	The figures in each case represent the average of five tests.
	Ultimate per square inch......	93,200	79,890	83,130	71,930	75,310	
	Per cent. elongation............	15.3	22.3	19.8	25.3	21.8	
	Per cent. reduction of area...	30.	38.7	40.7	42.8	46.1	

TABLE VI.—TEST RESULTS OF EYE-BARS WITH WELDED HEADS DIE-FORGED AND DIFFERENTLY ANNEALED.

Carbon, per cent.	Mark.	Elastic limit. Per sq. in. of section.	Ultimate strength. Per sq. in. of section.	Per cent. elongation in 45 inches.	Contraction of area. Per cent.	Broke.	Fracture.	Remarks.
.30	A	25,780	62,790	16.0	43.8	9.75 inches from pin-hole.	Fine and silky throughout.	Annealed from cherry-red in hot ashes.
	B	28,240	63,550	15.5	45.0	8.0 inches from pin-hole.		
	C	29,770	73,130	12.5	42.6	16½ inches from pin-hole.		Annealed twice from cherry-red—once in ashes, the second time in oil.
	D	28,030	68,330	10.8	44.2	About middle of bar.		
	E	32,330	68,760	10.5	46.3	About middle of bar.		Annealed from cherry-red in oil.
	F	33,580	67,990	12.2	45.8	About middle of bar.		
	1.	43,920	70,310	22.2	33 8	....		Test specimens cut from original bars before working. Section 1.072 sq. in.; Elongation in 10 inches.
	2.	43,980	70,690	22.8	41.4	....		

MICROSCOPIC ANALYSIS OF THE STRUCTURES OF IRON AND STEEL.

BY J. C. BAYLES, NEW YORK CITY.

AN obstacle to the more careful and satisfactory study of metals has been the difficulty in harmonizing the results of chemical and physical tests. These give us records of observations made from different and often widely separate points of view, and while it is true that they furnish bases for more or less accurate triangulations into the realm of speculation, it is doubtful if, with only the laboratory and the testing machine, our investigations would not move in parallel lines, leaving between them an unexplored field in which must probably be sought the information which shall connect the results of chemical and physical tests, and give to both a practical value which neither has yet been found to possess.

The use of the microscope in the study of metals is not a new thing, but it is only lately that it has begun to attract the attention it merits or to show results of tangible value to the metallurgist. Among recent valuable contributions to the literature of this subject, I have been especially interested in the work of Mr. A. Martens, of

Berlin, recorded in a paper contributed to the *Verein zur Befoerderung des Gewerbfleisses.* Some of the results of the investigations of this gentleman are sufficiently remarkable to merit consideration, as indicating the advantages of the microscopical study of the crystalline structure of metals.

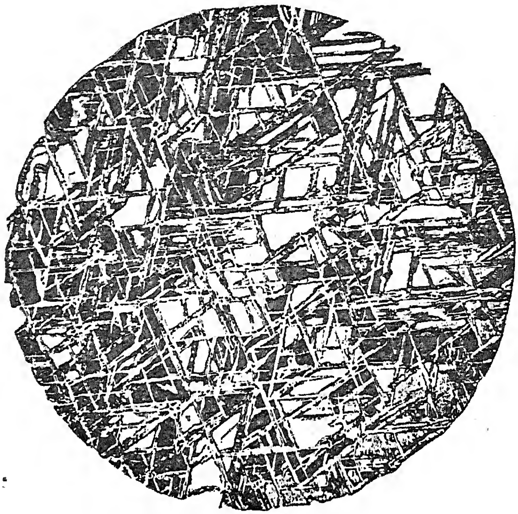
Mr. Martens, although acknowledging that so far he has not been able to obtain results which he would consider conclusive, is still confident that microscopic analysis will find a place as a rival of chemical analysis in the investigation of the composition of metals, especially iron and steel. It is doubtful if this opinion will be sustained. Certain peculiarities and characteristics, due chiefly to the various mechanical operations the material undergoes during the process of manufacture, or to molecular changes due to the manner in which it is strained in performing its functions as part of a mechanical structure, can probably be best and most satisfactorily investigated by means of the microscope; but we can scarcely expect that microscopy will supplant chemistry in determining the composition of metals. The microscope employed by Mr. Martens is of peculiar construction, having two ball-and-socket joints, by which it can be placed in any required position, while the more delicate adjustments are effected by the usual rack and pinion arrangement. The table upon which the microscope is mounted is provided with a large circular opening in which rests a semi-spherical table, the level surface of which serves to hold the object examined. By simply turning this table, the object can easily be brought into any desired position, so as to give the best inclination for light and observation. One of the main points in connection with Mr. Martens's experiments is the preparation of the specimens. He has examined sections of a large number of different specimens, the surfaces having been ground and finely polished, and then treated with acids, so as to clearly develop the crystals and fibres in the metal. In preparing the samples the small apparatus used in grinding lenses for optical instruments is used, such unimportant changes being made as were found necessary. The acid employed in developing the structure of the metal is greatly diluted, since it is found that the longer the time necessary in the process of developing, the more satisfactory the results obtained. For this reason the acid solutions employed by Mr. Martens are in the proportion of about one part of acid to one thousand parts of water. The preparation of the specimens is said to have required no great degree of skill, and to be easily carried out in workshops where the few necessary appliances are readily available.

Mr. Martens experimented upon a series of specimens of different materials, including tool steel, spiegeleisen, gray pig iron, plate glass, etc. He obtained as results a series of enlarged views of the fractured surfaces of the bodies in question, which are very interesting. He found that the fractured surfaces of bars which broke under continued use exhibited distinct features. Clearly defined portions or ellipses could be observed on surfaces of tool steel and plate glass, while within each portion of an ellipse could be seen, under favorable conditions, streaks, the prolongations of which beyond the ellipses ran in directions normal to the bounding surfaces of the broken pieces. This observation could almost always be made in connection with metals exhibiting a fine granular fracture, and the finer the granules the more distinct were the streaks mentioned. In tool steel these streaks could be seen with remarkable clearness. These phenomena appear only within certain limits, and when these limits are passed, the material exhibits a fracture commonly observed in flint, glass, and like substances. But even in fractures of such bodies, surfaces bounded by portions of ellipses and having distinct streaks running in a direction normal to the ellipses may be observed. These normal streaks were found to consist of prismatic elevations which passed through the area inclosed by the ellipse, and were arrested by the outline of the ellipse, which also projected from the common level of the surfaces, coinciding, however, with the latter at the ends.

From his various examinations Mr. Martens concludes that sudden cooling of molten masses of metal favors greater uniformity than slow cooling, this having, in his judgment, been shown very conclusively by a protracted study of different samples of pig iron. He thinks that conclusions as to the use to which pig iron and steel may be put may, in a great number of instances, be based upon examinations of this kind, and that the method will very often be found to be sufficiently trustworthy for all practical purposes.

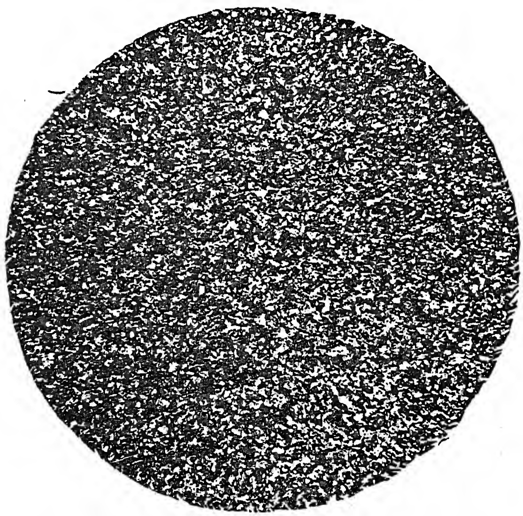
Another valuable contribution to the literature of this subject was recently made by Dr. H. C. Sorby, of Sheffield, in a lecture on the "Microscopical Structure of Iron and Steel." Dr. Sorby, it appears, was first induced to investigate the subject as bearing on the structure of meteoric iron, and the results which he obtained are certainly of great interest. Dr. Sorby prepared his specimens substantially as described in another portion of this paper, the development of the structure being attained by the use of weak acid. This development is due to the fact that some of the constituents of the

specimen are not acted upon at all, and others in varying degrees. He observed that portions of slag or cinder remained in their.



Meteoric Iron, showing a Structure unlike that of any Artificial Iron.

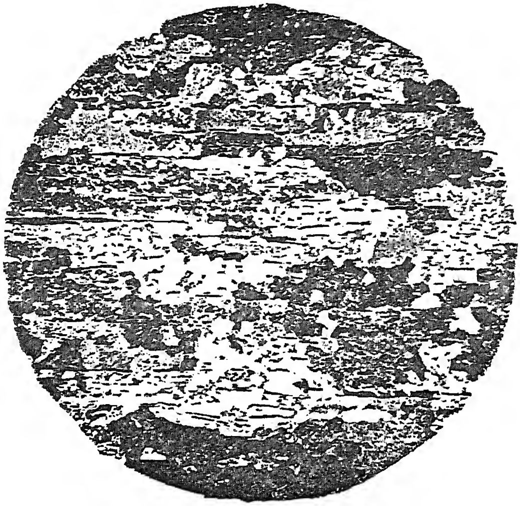
original state, and were seen as black specks or patches of varying size and shape. Some constituents of iron and steel remain per-



Cast Steel, showing Uniform Structure with no Lines of Weakness.

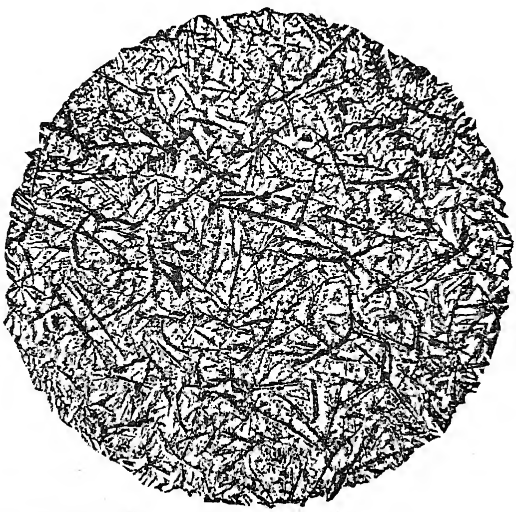
fectly bright and brilliant, while others become coated, to a varying extent, with a brown film, so as to show the outlines of the individual

crystals very perfectly. Other constituents, again, are so acted upon as to develop a very close-grained structure, which shows colors of



Armor Plate, showing Varying Crystals and Lines of Welding, etc.

varying brilliancy. Thus, by difference of color or other characteristics, the outline of the individual crystals and their own inti-



Cast Iron, showing Plates of Graphite, which make it Weak.

mate structure are shown to great perfection. Dr. Sorby further states that the thorough determination of the exact nature of all the

constituents seen in the various specimens would involve many years of careful chemical and microscopical investigation, since, though many of them differ very greatly in microscopical and physical character, their size is so small that it would be difficult or impossible to separate them in such a manner as to determine their chemical constitution, and it would consequently be necessary to ascertain their true nature by careful induction from facts observed under special circumstances. So far as could be learned with the microscope, Dr. Sorby found various kinds of iron and steel to contain at least seven well-marked constituents. Starting with pure iron, he found what are probably three well-marked compounds of iron, with varying amounts of carbon or other substances met with in small quantities in different sorts of iron and steel, portions of included slag, well-marked crystals of graphite and small crystals that may be silicon. Dr. Sorby has prepared a number of illustrations of the structure of various kinds of iron and steel. Several of these illustrations have been kindly furnished me, being heliotypes from photographs obtained directly from the specimens in question. The samples in question comprise armor plates, meteoric iron, cast iron and cast steel, and, as an inspection will show, exhibit a greatly varying structure. The specimen of cast steel is of very uniform structure, with no lines of weakness, while an inspection of the specimen of cast iron will reveal a number of plates of graphite that naturally tend to diminish the strength of the metal. The armor-plate, on the other hand, shows varying crystals and lines of welding, while the sample of meteoric iron shows a structure altogether unlike that of any artificial iron.

Dr. Sorby's paper is of such interest that the following abstract taken from a report received some time since will undoubtedly meet with favor: Commencing with various kinds of cast iron, it was shown that their structure was sometimes greatly modified by the presence of crystalline plates of graphite, over which was deposited what was probably free iron, the interspaces being filled by what were considered to be two distinct compounds of iron and carbon. In other cases, the structure was mainly dependent on the crystallization of the iron itself, the graphite being thrown off toward the close of the process. In the case of white refined iron, the principal constituent was probably an intensely hard, white iron, with much carbon, associated with which were one or more of the other compounds of iron and carbon always present in gray iron. Various kinds of wrought iron were next considered. A hammered bloom

was shown to consist of an irregular mixture of crystals of iron and portions of slag. When rolled out into a bar, those portions of slag not expelled were thrown out into long threads, and the crystals of iron seen in the bar were not the original crystals of the bloom, but fresh crystals formed in cooling. This conclusion was based upon the fact that they exhibited little or no tendency to elongation in the line of the length of the bar, as they probably would if the original crystals had been drawn out by the process of rolling. The fibre seen on fracturing such specimens of wrought iron was mainly due to the elongation which occurred during the fracture, and was not a characteristic of the iron. In this connection Dr. Sorby exhibited the specimen of armor plate to which I have referred, and all of those kinds of iron that are employed in the manufacture of steel by cementation.

The change of structure produced by this process is very striking, the most characteristic feature being the development of a network of flat crystals of an intensely hard compound of iron and carbon, scarcely acted upon at all by dilute acid, so that the rest of the steel may be dissolved away and the compound in question left in sufficient relief for prints to be taken as from a woodcut. The difference between the structure of the outside of the converted bars, where this hard compound of iron and carbon had been developed, and of the interior of the bar, was shown to be very great, and mainly due to recrystallization of the iron. Ingots of cast steel produced by melting blister steel had a totally different structure, which depended in the first place on large crystals, and in the second place on the minute microscopical structure of these crystals. The principal difference between the structure of such an ingot and that of hammered bars was that the whole mass was made more uniform and the grain very much finer by hammering. This was still more the case when the hammered steel was hardened, in which case the constituent crystals were so small that it was very difficult to learn much about them by microscopical study. It will be seen by an inspection of the specimens of meteoric iron shown in one of the heliotypes above mentioned that it differs considerably from most varieties of commercial iron, and though alloys of iron and nickel of the same composition as meteoric iron were melted and slowly cooled, nothing at all resembling the structure of meteoric iron was obtained. It was found, however, that the closest approach to this structure was in the case of iron that had been kept for a long time at a high temperature, but not actually melted, under which condi-

tions some varieties of iron containing little carbon crystallized in large crystals having some of the principal characteristics of meteoric iron, while iron containing a certain amount of carbon crystallized in a manner imperfectly resembling the crystallization of meteoric iron. In this artificial preparation, however, there was crystallization of varying compounds of iron and nickel, and from these facts Dr. Sorby concludes that meteoric iron probably crystallized very slowly at a temperature below fusion.

From what precedes it will be seen that the results thus far obtained are more interesting than valuable, but the value of any interesting scientific fact depends simply upon how soon we shall have more facts to put with it. Those for whom this subject has interest will derive benefit from studying results reached and the methods followed by Mr. A. F. Hill, of the membership of this Institute, in his investigations of the cause of the fracture of the beam-strap of the steamer Kaaterskill,* and in his discussion of the cause of breakage of the connecting-rod of the chain-cable testing-machine at the Washington Navy Yard.† These are investigations of the greatest interest and value, conducted with much care, and pointing to conclusions which could not have been reached by analysis or test. In fact, either or both of these methods in the cases named would probably have led to erroneous conclusions.

The conditions of success in the employment of the microscope in the examination of iron and steel are:

1. A careful and thorough preparatory training of the eye.
2. Proper preparation of the specimens.
3. Correct choice of instruments.
4. An inexhaustible fund of patience.

There is no kind of scientific work to which Schelling's maxim, "In order to see aright, we must know what to look for," applies with greater force than to metallurgical microscopy. This soon becomes apparent to the beginner, and is frequently a source of almost complete discouragement. But before the use of a microscope (simple or combined) can serve any useful purpose, the naked eye must be thoroughly familiarized with the characteristic appearances of metals.

Any one without previous practice who tries to promptly decide from outward appearances whether a piece of metal is iron or steel, or even to distinguish positively between wrought iron and cast iron,

* The Iron Age, October 12th, 1882, p. 1. † Ibid., January 4th, 1883, p. 1.

is tolerably certain to meet with a series of sometimes rather mortifying failures, which will soon induce him to look far longer and more closely at a piece of metal than he ever did before. By much handling of metal, one soon gets at the difference in the feeling to the touch and the difference in the weight, and all those other physical attributes by which the other senses render assistance to the eye. Given, for instance, a couple of round-rolled bars of equal diameter and equal length, the one of iron and the other of steel, and an experienced blacksmith will be able to pick out the steel from the iron almost without looking, simply by the difference in the feeling and in the weight—trifling though these differences are—just as a jeweller or cashier at a desk can decide in the dark whether a given piece of metal is gold or silver, by simply feeling of it. But such help to the eye is apt to embarrass rather than facilitate microscopic work, and it is best to learn early to rely upon the eye alone, without touching the metal.

The first step to be taken in training the eye consists in a careful study of fractures of every description and on every available occasion. Characteristic fractures—that is, fractures of good cast iron, of good wrought iron, of ingot steel, of rolled tool steel—placed side by side, should be studied first, and the obvious differences in their appearance well impressed upon the eye. The recognition of one distinctive feature in each of these four fractures at a first study will be a remarkable progress. Many confound the general impression gained by such a study with a knowledge of distinctive features. The beginner can readily satisfy himself of the value of the knowledge thus gained by comparing the fractures of different metals which are similar in appearance, as, for instance, rolled soft steel and fine wrought iron. The result is likely to be slightly disappointing. After having well impressed upon the eye and memory characteristic differences, he may commence to study the series of characteristic similarities, noting every shade of color—and a very fine "harmony in gray" it is—every variation of texture, of form, etc. For whatever is dissimilar among similar characteristics, an explanation should be sought. This is often more easily obtained from the blacksmith than from the man of science. At all events, the blacksmith knows a great deal which is worth finding out. He may be hampered by lack of power of expression and by crude or wrong notions, but if one can draw him out it will be singular if an hour's conversation with him will not amply compensate for the time given to it. After the naked eye has become familiarized with the distinctive features

of fractures, the student would do well to go over precisely the same ground, and in the same order, armed with a good hand lens. A power of from two to three linear diameters is amply sufficient for the first studies, but care must be taken that the lens be absolutely achromatic. The first studies will prove revelations. Forms and features never before thought of now become apparent, and with it comes the irresistible desire for a knowledge of the internal structure. This leads to the development of the internal structure by treatment with acid. Sections planed to a well-finished surface answer the purpose at first. If the finish obtained by the cutting tool is not good enough, complete the work by draw-filing in the direction of the fibre. The surface thus obtained may be treated with only slightly diluted nitric acid, but must not be exposed more than a few minutes at a time to the action of the acid, which should be washed off under a running stream of water as soon as the whole surface treated has become oxidized and begins to show brown streaks. Continue this, alternately treating with acid and with cold water, for from half an hour to an hour. In the final washing use a jeweller's soft brush, and satisfy yourself that no acid remains on the surface by testing the water which runs off with litmus-paper. Then dry quickly with clean cotton waste. The development thus obtained will naturally be a coarse one, but it has the advantage of bringing out clearly the characteristics of the structure. If the material is fibrous the fibre will show plainly. If the latter has been distorted by mechanical treatment, under the hammer or otherwise, these distortions will show also. If the structure of the material is crystalline, a sort of coarse tracery will develop on the surface, resembling, under the magnifying glass, a network of cracks. This sharp acid treatment is rather ephemeral in its results, as with the most careful washing the development obtained will rust out in a short time, but it is, nevertheless, an excellent means of quickly obtaining the characteristics of the internal structure, and of studying and impressing upon the eye and memory its marked features, serving the purpose of a rough contour sketch in the study of a fine or intricate drawing.

For fine developments the conditions of treatment are more tedious and more complicated. In the first place, the surface to be treated must be, as nearly as possible, a true plane. None but the very best planer work and subsequent grinding with either fine emery or under a metallic mirror grinder will answer for this. The surface thus obtained is then treated with highly diluted nitric acid—about 1

part of acid to 300 parts of water—in the following manner: At first, put the acid on with a camel's-hair brush, and as soon as oxidation begins, as shown by the formation of small bubbles on the surface, wipe the specimen dry. Repeat this until all the oil that may adhere to the polished surface has been removed, and the acid is free to act uniformly upon all parts of it. It is of importance that this be carefully observed, or else the acid will attack the metal in spots, and thus destroy the evenness of the surface, which, under a powerful lens, leads to deceptive results that are rather annoying. A thorough development with such highly dilute acid requires from twenty-four hours to five or six days, according to the chemical composition of the iron or steel under investigation. The more highly dilute the acid, the longer the time required for the development—but, on the other hand, better results are obtained. After you have assured yourself that the acid does act upon the entire surface, the specimen may be treated by simply immersing it—polished face downward—to a depth of about $\frac{1}{16}$ of an inch. To this end the acid is poured in a porcelain or agate-ware tray or dish in sufficient quantity to just stand above round glass rods which are laid in the bottom of the tray and serve as rests for the specimen, to prevent the surface to be treated from coming in contact with the bottom. The acid should be changed at least every twelve hours, and the specimen washed off with a jeweller's soft brush in clean cold water. After washing, examine the development under water, so as to prevent oxidation, and, when it is complete, wash off all acid thoroughly until the water running off will not affect litmus-paper, then wipe thoroughly dry, with cotton waste at first and finally with a soft chamois skin. A drop or two of kerosene oil rubbed over the surface with the chamois skin will preserve it from oxidation for a long while. But should it take place before the examination of the specimen is finished, or before a good photograph of it can be obtained, the whole surface must be treated all over again.

The foregoing applies only to large surfaces of, say, several square inches. If the development brings out crystal sections, or if it is desired to examine the crystals or the structure of a fracture under a powerful magnification, then the specimen must be prepared for the microscopic slide. This is done in the following manner: A very thin section of the part of the surface to be examined is obtained by planing down from the back to a thickness of $\frac{1}{32}$ to $\frac{1}{16}$ of an inch. The planed back is then fastened with cement to a glass slip, and the surface to be examined is filed flat, and afterward

ground to a perfectly even surface on a fine whetstone, without any tearing or burnishing. Care must be taken to give this surface, in the final finish, so delicate a polish that it shall leave even the most minute particles of metal undisturbed and free from polished grooves or scratches. This carefully prepared surface is then treated with highly dilute nitric acid, and the action of the acid closely watched. After being in the acid for a short time it is taken out and examined under water as before explained. When the etching is thought to be sufficient for obtaining satisfactory results (and this is entirely a matter of practice), the specimen is thoroughly washed, quickly dried, and a thin glass, square or circular, mounted over it with Canada balsam. The specimen is now ready for microscopic examination.

As was said before, the simple microscope is the proper instrument for the beginner in this kind of work. It is a common mistake with novices to judge the excellence of a microscope by the amount of its magnifying power. The fact is that no object should be viewed with a power greater than is needed to clearly show its structure, and, if this can be done with twenty diameters, it is folly to use a hundred. Moreover, the gradual increase of power applied in the study of internal structures has the advantage of giving the student an opportunity to familiarize himself with the results obtained with the lower powers, and thus to find readily those more minute developments which the application of the higher powers reveals.

After becoming familiar with the use of the simple microscope, and the developments suited to its powers, work may be begun with the compound instrument. It must be borne in mind that in low-priced instruments the actual and angular apertures of the objectives are small, the corrections not so exact as in those of higher grade, and that they are therefore liable to give false impressions of the object under examination; besides, it is impossible to view an opaque object by reflected light satisfactorily with any of the cheapest forms of compound microscopes, since the lenses approach the object too nearly, and are far too small to admit of a proper illumination ot the object.

In making the selection of a microscope, the following points are important to bear in mind:

It is essential that the lenses should give good definition—*i.e.*, should show objects clearly and well-defined.

The stand should be of good material and workmanship; there should be no "shake" or lateral motion in the adjustments for focus; there should be no "lost motion"—that is, the focus should be in-

stantly changed by the slightest motion of the milled heads, and for metallurgical work, which deals with opaque objects only, there should be a universal joint for inclination, which will be found a great convenience in observation. For beginners, one of the best practical treatises on the subject is Dr. Phin's *Hints on the Selection and Use of the Microscope.* For further details regarding the preparation of slides the student would do well to consult any of the numerous hand-books on the subject, one of the best of which is Thomas Davies', *The Preparation and Mounting of Microscopic Objects.* One thing, however, should not be lost sight of, and that is, that besides delicacy of touch and infinite patience, the most exquisite cleanliness is an indispensable condition of success. Dust and moisture are the microscopist's worst foes.

Concerning the results to be expected from the microscopic analysis of metals, it would, at this stage, be judicious to speak with caution. I believe it opens a vast and as yet unexplored field, especially in connection with materials of construction, such as iron and steel. The progress of the past twenty years in the methods of making and testing these metals has revealed the close relations existing between their chemical composition and physical properties. There remain, however, many gaps in our knowledge of these materials, largely the result of changes produced by mechanical treatment, and for the study of these we are necessarily dependent upon the microscope. This instrument seems to furnish the best means of investigating these peculiar and as yet mysterious structural changes, which are discovered, but not explained, by the testing machine. To these changes are probably ascribable the many surprising discrepancies which occur in the mechanical qualities of material of a given chemical composition, and it is but fair to assume that microscopic examination will greatly diminish the rather liberal use of the word "unaccountable" in those cases. Perhaps one of the first and simplest results to be expected will be the explosion of the theory of cold crystallization of iron under stress, strain, shock, or vibration, to which so many hold with such tenacity, and which is assumed to account for fractures showing apparently crystalline structure. Development with acid and subsequent microscopical study, show that well-defined crystals are present in many forms of rolled and hammered iron, and, in fact, that they are only destroyed when the rolling is carried to such an extent as to change the whole structure of the metal, as in plates, sheets, and bars of small section. In many other ways, it is probable, the microscope will show that there is

nothing so delusive as the crude experience which has been held to prove a great many things at variance not only with the probabilities but with all the analogies of nature.

It may sound like a misapplication of terms to speak of the anatomy and physiology of iron and steel, and yet the most advanced metallurgists have long felt the want of the kind of knowledge, or rather information, which could properly be classified under these terms. There are many limitations placed upon the work of the chemist, and the results obtained with the testing machine indicate far more, as Dr. Sorby points out, the lines and planes of weakness and the divisions between the constituent crystals, than the actual structure of the metal and the co-relations of the crystals. In many cases the faces of fractures are apt to lead to erroneous conclusions as to the composition of the metal or the cause of its failure. But when, instead of the fractured surface, a polished longitudinal or cross-section comes under observation, with the internal structure of the material revealed by careful treatment with acids, the conditions of observation are entirely changed, and by the aid of the microscope we are, as it were, furnished with the missing link in the chain of evidence required for a correct conclusion as to the nature of the material under investigation.

The suggestions of this paper should be received with the understanding that as yet very little has been accomplished in the way of practical microscopic analysis. Much is to be learned in regard to the proper treatment with acids, and many difficulties in the construction of entirely suitable instruments for the purpose have yet to be overcome. Nevertheless, there is no longer any question as to the important place the microscope must hold henceforth in metallurgical inquiries, nor as to the magnificent field it has opened for investigations of an entirely novel character, the results of which cannot but prove of great value to the practical metallurgist.

THE METALLURGY OF NICKEL IN THE UNITED STATES.

BY WILLIAM P. BLAKE, F.G.S., NEW HAVEN, CONN.

THE metallic element Nickel, discovered by Cronstedt the mineralogist, in the year 1751, as a peculiar metal in kupfer-nickel, remained for a long time comparatively unknown in its true charac-

ters. It was at first obtained as a secondary, or by-product, in the manufacture or extraction of cobalt, being found concentrated in the cobalt speiss, left in the pots when smalt or cobalt-blue glass was manufactured. Cobalt at that time was the product chiefly sought, and nickel in its applications was unknown. Since the discovery of the artificial ultramarine blue, the demand for cobalt has been lessened, while the increasing uses of nickel have made it of first importance, and the conditions are thus reversed.*

But the nickel so produced from the residues was contaminated with copper, iron, or arsenic, and in this condition it entered into the composition of the familiar alloy commonly known as German silver, but properly known as nickel-silver.

The so-called nickel or nickel bronze was a complex, irregularly constituted alloy, in which less than one per cent. of arsenic was sufficient greatly to modify its physical properties. And it was difficult to free the metal from this element. It may be said that, until within a few years, the element nickel, in its true characters and in a comparatively pure condition, was commercially unknown.

To the scientific chemists, however, its true physical properties early became known, though not without some contradictory and varying results, at first, resulting no doubt from minute differences of composition of their samples, according to the nature of the processes employed for the extraction of the metal. Richter found that nickel oxide, strongly ignited in an earthen crucible with carbon, gave the metal in a perfectly malleable, ductile condition. It could be hammered cold or hot into plates $\frac{1}{100}$th of an inch in thickness, and could be drawn into wire $\frac{1}{56}$th of an inch in diameter.† Its malleability was found to be diminished by carbon or manganese. On the other hand, Tupputi found that nickel reduced in the presence of carbon in a covered charcoal crucible and under glass, formed more or less nickel-graphite, absorbed a portion of carbon, and was less ductile than zinc. It was brittle when cold, and was as fusible as cast iron (Erdmann), while the metal obtained by Richter was difficult of fusion. He also noted that nickel could be welded, but Tourte found that it welded but imperfectly.

Deville cited cobalt and nickel as metals with useful physical properties but little known, such as malleability, ductility, and a tenacity surpassing that of iron. He showed that these metals could be worked at a forge with the same facility as iron; that they were

* See Daubrée, *Substances Minérales*, p. 158.

† Cited in Gmelin, V., 361.

susceptible of being employed in the same manner and were less oxidizable.*

Inasmuch as nickel first became known commercially in the industrial arts in the form of an alloy, there were no special attempts to produce the metal in a state of extreme purity. The nickel-silver of commerce answered all the existing demands, and was of course much easier to make, and cheaper than the pure nickel. It found a large and rapidly extending consumption as a substitute for silver spoons and forks and for silverware generally, especially when the new art of electro-plating was developed by Spencer, Smee, and others. The nickel-silver was specially well adapted to receive and hold the deposit of silver, and it is to this day the most desirable alloy for plating.

The use of nickel alloy for small or subsidiary coins next made an increased demand for nickel. Tentative efforts were made by Dr. Feuchtwanger, in New York, in the year 1837, and he actually issued many small one-cent and three-cent pieces, made of a nickel alloy, the exact composition of which he was careful not to state, but called it "Feuchtwanger's Composition." Switzerland commenced using nickel alloy coins in 1850; the United States in 1857, though sample coins, one-cent pieces, had been made by Prof. James C. Booth, at Philadelphia, in 1853, the proposed alloy containing from 5 of nickel and 95 of copper, to as high as 30 of nickel, and 70 of copper. The alloy adopted by law consisted of 12 of nickel and 88 of copper. The five-cent pieces now in circulation are made of an alloy of 25 parts of nickel and 75 parts of copper. In 1860, Belgium adopted an alloy of the same proportions, for small coins. Other countries have followed, until the use of nickel alloy for small coins may be said to be almost universal in the chief commercial countries. Up to June 30th, 1876, the United States had alone issued the five-cent nickel to the extent of $6,716,129 in value. Another sudden demand for a larger supply of nickel sprang up when the art of depositing nickel by electricity was perfected. The many and increasing applications of this art need not be here enumerated. It is sufficient to state, that at the present time, they constitute a large part of the present consumption of the metal in this country, where the art may be said to have originated in a successful, practical form.

Nickel ore is more generally distributed throughout the mineral-

* Comptes Rendus de l'Académie.

bearing portions of the United States than is generally supposed. It is commonly associated with chrome ores from Canada to Maryland, on the Atlantic side, and equally with the chrome ores of the Pacific slope, notably in Oregon. It is also a common associate of magnetic pyrites in the Archæan rocks, being found in Litchfield County, in Connecticut; in the Highlands of the Hudson, in New York, and in New Jersey; and specially at Lancaster Gap, in Pennsylvania, where the chief supply of nickel has been obtained for the United States. This ore yields from 1½ to 2 per cent. of nickel, but is enriched by smelting at the mine into a matte containing 10 per cent. or more of the metal. This locality was worked some thirty years ago by Prof. Jas. C. Booth and others, of Philadelphia, and some nickel alloy was made. Some ten years later Mr. Joseph Wharton purchased the works and established the industry at Camden, N. J., opposite Philadelphia, where it has since been carried forward.

A large portion of the metal produced at these works by Mr. Wharton has been used at the United States mint for the subsidiary small coins, and a considerable amount has been exported. Since the development of nickeling by galvanism, a large part of the product has been put into the form of nickel salts and anodes.

But Mr. Wharton, not being content with the production of impure nickel, early commenced experimenting to determine whether nickel could not be produced in a pure and malleable condition, susceptible of being worked in nearly the same manner as iron, and of being applied in the manufacture of various objects, requiring strength of material and a material that cannot be easily oxidized. One of his earliest experiments was to take the somewhat spongy mass, got by reduction of the oxide of nickel, and, after heating it to full redness, work it under a steam-hammer into a bar.

In 1873, Mr. Wharton sent to the Vienna Exhibition a sample of nickel in the form of axles and axle bearings, and at the Exhibition in Philadelphia in 1876, he exhibited a remarkable series of objects made of *wrought nickel,* such as bars, rods, a cube, a horseshoe magnet, and magnetic needles of forged nickel. These did not excite the interest to which they were entitled as a remarkable advance in the working of this little-known metal. The exhibit did not cause much comment, and it was not specially described or reported upon, so far as I am aware, except by the judges who reported the exhibit to the Commission as worthy of an award in the following terms: "A fine collection of nickel ores from Lancaster County, Pa., with

nickel-matte, metallic nickel in grains and cubes, and manufactured nickel, both cast and wrought; nickel magnets and magnetic needles, cast cobalt, electro-plating with nickel and cobalt, and salts and oxides of both these metals; the whole showing a remarkable degree of progress in their metallurgical treatment."*

Some of the same objects, formed of wrought nickel, were sent over to Paris two years later, and were exhibited in the American Section in 1878. There, as in Philadelphia, they did not at first excite any surprise, or receive any special attention. Very few persons realized what the objects really were, and that they were very different from *alloys* of nickel. In fact, very few chemists had ever seen *nickel*. Pure nickel was a rarity, a curiosity, just as samples of indium or thallium are to-day.

You can then, perhaps, imagine the incredulity of the expert chemists and metallurgists of Europe, when whole ingots and forged bars of metal and numerous finished articles of pure wrought nickel, without alloy, were offered for their inspection. These articles not differing greatly in their appearance from the higher grades of nickel alloys, or from electro-nickeled objects, they passed them without surprise. No previous exhibition had been so rich in exhibits of the use of nickel and in the products from them. The influx of the pure carbonated and oxidized ores from New Caledonia, had greatly stimulated the nickel industry in Europe, and had improved the quality of the alloys of nickel. New companies had been formed to manufacture nickel-silver and to produce nickel from these superior ores, at a lower cost than had before been possible. Christofle of Paris had just erected extensive works at St. Denis, and had made a most brilliant display of his products in one of the main avenues of the Exposition. The Vivians of Swansea and other exhibitors had large cases filled with beautiful objects of hollow and solid ware made of nickel-silver. Amid these various exhibits of striking *tours de force*, the modest little show-case from the United States with examples of manufactures of *pure wrought nickel*, not alloy, could hardly be expected to excite attention and win the golden award, which was most cheerfully accorded as soon as the fact was demonstrated by analysis that the objects were really of the pure metal. Some of the objects now shown were at that exhibition, and have retained their brilliant polish and lustre unimpaired. These notable advances in the me-

* Reports and Awards, Group one, 640, p. 470.

tallurgy of nickel, made with the lean and sulphuretted ores of Lancaster Gap, prepared the way for greater advances.

Dr. Fleitmann, of Iserlohn, Westphalia, Prussia, has improved and cheapened the operation of refining the nickel and toughening it, and has reduced the liability to the presence of blow-holes in castings by adding to the molten charge, in the pot, when ready to pour, a very small quantity of magnesium. This is immediately oxidized, magnesia is formed, and graphite is separated. It would seem that the magnesium decomposes the occluded carbonic oxide, or reduces it to a minimum. The magnesium must be added with great care, and in small portions, as it unites explosively with the charge. It is stirred in. About one ounce of magnesium is sufficient for 60 pounds of nickel. Three-quarters of an ounce to 54 pounds of metal has been used with success by Mr. Wharton. The nickel from the ore at Lancaster Gap seems not to require as much as the foreign metal. It is to be noted that complete malleability of nickel was obtained at Wharton's works in Camden, before Fleitmann's invention or process, but this last is more rapid and better than the old method. The metal so treated becomes remarkably tough and malleable, and may be rolled into sheets and drawn into wire. Cast plates can be successfully rolled. The cast plates, such as are made for anodes, after reheating, are rolled down to the desired thickness. It is found that it is a great improvement to the nickel anode plates to roll them down. They dissolve with greater uniformity in the bath. Nickel so treated with magnesium has been rolled into sheets as thin as paper. Expensive works for rolling the metal have been erected by Mr. Wharton at Camden. There are already two trains of 40-inch rolls, 18 inches in diameter, with annealing ovens and gas furnaces and their adjuncts, and a 90 h.p. engine. At present this mill, as well as the works for producing the metal, and the mine, also, are "shut down."

The largest sheet yet rolled at Camden was 72 inches long and 24 inches wide, of pure nickel.

Dr. Fleitmann has also succeeded in welding sheet nickel upon iron and upon steel plates, so as to coat them equally on each face with a layer of nickel. The quantity preferred by weight is $\frac{8}{10}$ iron and $\frac{2}{10}$ nickel, one-tenth of nickel being placed on each surface. To secure union, the iron or steel must be perfectly flat and clean. A pile is made with outer facings of sheet iron to protect the nickel from scaling. When the whole is heated to the proper degree, it is passed through the rolls. The two metals become so firmly united that

they may afterwards be rolled down two or three together, or separately, to the thinness desired.

The samples exhibited were cut from sheets made at Mr. Wharton's works at Camden. One sample, No. 20 gauge, 10 per cent. nickel; one sample, No. 22 gauge, 10 per cent. nickel; one sample showing edge of sheet.

These are all examples of nickel upon iron. I also show a thin sheet of pure nickel annealed. The physical properties of the two metals, iron and nickel, are so nearly the same that they work well together. The nickel surface cannot be removed or regained in the scrap and waste except by dissolving out the iron core by dilute sulphuric acid. In the earlier experiments, the ingots or cast plates were beaten under the hammer; this produced a great deal of scale and waste, as with iron, but this is now avoided, partly by the device of a thin covering of sheet iron which is afterwards dissolved off. Dr. Fleitmann has produced steel plates and steel wire similarly coated, and proposes to make nickeled boiler plates.

The applications in the arts of such nickeled iron sheets as I have described, will readily suggest themselves. Up to this time the most direct uses seem to be in making hollowware, particularly culinary vessels. The manufacture has already begun at Schwerte by Dr. Fleitmann, and a great variety of vessels, such as saucepans and kettles, have been turned out, some of them of pure sheet nickel. They are all very beautiful in appearance, resembling highly finished platinum vessels more than ordinary ware. When planished and buffed off, the surface becomes like a mirror and will answer the purpose of one. The small vessel exhibited is made of nickeled iron, and will show the facility with which the compound sheet metal may be stamped, spun up, and polished. Much larger specimens of ware might be shown.

This ware is believed to be far superior to tinned iron or tinned copper for cooking in. The nickel is not only less liable to corrosion, but is harder, will wear longer and cannot be melted off by overheating. The ware is lighter and stronger than tin or copper ware; is susceptible of a high polish and is not easily tarnished. It appears to be well adapted to the manufacture of dishes, salvers, and covers for the table. The coating of nickel applied by welding is stronger and tougher than that deposited by electrolysis, and appears to be less liable to scale off. The electrically deposited metal is in some cases very brittle, and no doubt contains sufficient hydrogen essentially to modify the physical characters of the coating.

My purpose in this article is chiefly to record some of the most notable advances in the metallurgy of nickel made in the United States, and particularly to direct attention to the production by Mr. Joseph Wharton at his works in Camden, before the year 1876, of *pure nickel* in a malleable state and in considerable quantities, and the manufacture of useful articles from it by forging and working it in the same manner as iron is forged and worked; thus exhibiting for the first time, in the "large way," the true physical characters of this metal, and its adaptation to many purposes in the arts, as had already been partly indicated, in the "small way," by scientific chemists in their laboratories.

I also desire to direct attention to the improved magnesium process of Dr. Fleitmann; to the manufacture of nickeled iron and steel in rolled sheets, and to the industries which the possession of pure nickel in commercial quantities renders possible.

EXPERIMENTS ON AMERICAN WOODS.

BY PROF. S. P. SHARPLES, EXPERT TENTH CENSUS, BOSTON, MASS.

UNDER the act providing for the taking of the Tenth Census, the superintendent was authorized to appoint experts to inquire into special industries; accordingly Professor Charles S. Sargent was appointed to gather statistics in relation to the forest industries.

As chief of the Department of Forestry of the Tenth Census he has been busily engaged in this work since the fall of 1879. Soon after his appointment he became convinced that it would be desirable to make an examination of the fuel-value of the various woods of the United States, and this work was placed in my hands.

At the same time I made the suggestion that while we had the opportunity, it would be well to test also the strength of these woods. The suggestion was adopted and Professor Sargent at once set his agents to work in various parts of the country to collect specimens of all the trees growing in their localities, employing as a rule botanists who were familiar with the flora of the region in which they were at work. The result of this work was the collection of over thirteen hundred specimens of wood, comprising over four hundred species and varieties, nearly one hundred of which had not before been described as trees existing in the United States.

The ash and specific gravity of every specimen in this collection have been determined, in most cases in duplicate, about 2600 ash and 2800 specific gravities determinations having been made. About 325 species were further tested for transverse strength and resistance to crushing. In this series about 1300 specimens were tested. As each of these was tested in three different ways, it made in all about 3900 tests. The specific gravity of each specimen in this last series was also determined, thus making in all about 10,600 tests that were made on the specimens. Many of these tests, however, included not only a single test, but often a series of tests that required at least ten entries on the final report, as I shall explain further in this paper.

In addition to the tests already spoken of, 70 tests were made of the carbon and hydrogen in a like number of specimens.

These tests have already, so far as the results of the ash and specific gravity of the dry wood is concerned, been published in *Forestry Bulletin* No. 22. The carbon and hydrogen determinations are to be found in *Bulletin* No. 18, while the tannin in the bark of a few of the most promising trees is found in *Bulletin* No. 24.

A *Bulletin* shortly to be published is to give the deflections under various loads of the woods tested in this manner, and the weight under which they failed, together with the force necessary to crush, in the direction of the fibre, pieces, whose length was equal to eight diameters. In addition to the tables published in the *Bulletins*, the final report will give the force necessary to indent the wood.

This series of tests is felt to be incomplete in many ways, and with the experience that has been gained in the work could doubtless be improved. A brief description of the methods used may be of interest.

Each specimen as soon as received was given a number, and this number has been constantly repeated in all the work done on that specimen; it is designated in the reports as the office number, and wherever met with always refers to the same tree.

After numbering, the sticks were at once sawed into bars five centimeters square. These pieces were then seasoned by air drying. During the first winter they were kept in a room warmed by a stove to about 70° F. After that they were removed to a timber-loft at Watertown Arsenal, where they were kept until they were dressed for the final tests.

Two blocks of fifteen centimeters in length were taken from each specimen and dried rapidly with steam-heat until they had lost most

of their moisture. From these pieces, blocks of exactly 10 centimeters in length and about thirty-five millimeters square, were dressed out. These were then placed in an oven which was maintained at a constant temperature of 100° until the blocks were perfectly dry. After they had ceased to lose weight, they were carefully measured with a micrometer caliper and then weighed. From the measurement and weight it was easy to calculate the specific gravity.

The ends removed from these blocks were used for determining the ash. They weighed from 10 to 20 grams and thus gave quite appreciable amounts of ash. The ash was determined by drying the wood in the same manner as the specific gravity blocks, then carefully burning in a platinum dish in a muffle-furnace heated by gas. The heat was so regulated as to burn the ash perfectly white without melting it. In most cases the ash was left in the exact shape that it occupied in the wood. It was judged best to report the ash exactly as found, and not to attempt to make any correction, on account of carbon dioxide that might have been lost from the calcic carbonate present.

From these results, the approximate fuel-value was calculated, assuming that equal weights of all woods have the same fuel-value. This value is supposed to be given more correctly by taking as the weight of the wood, not the specific gravity, but the weight of a cubic decimeter, minus the ash contained in it. The ash evidently adds nothing to the fuel-value, while it does add to the weight. This assumption, which is the one generally made, is not strictly true, but it is near enough for all practical purposes. It is founded on experiments made by Count Rumford and Marcus Bull.

The carbon and hydrogen determinations were made by burning fine sawdust in a platinum boat in a current of oxygen and collecting the products in the usual way. These analyses were calculated on the dry wood. The determinations may be conveniently divided into two classes—those of the coniferous woods and the non-coniferous.

The coniferous woods examined, with two exceptions, gave larger amounts of carbon than the hard woods. These two exceptions were the common white cedar or *arbor vitæ* of the North, and the black spruce or *Picea nigra*, neither of which would be selected as valuable fuel. The average composition of twenty-nine specimens of coniferous woods examined was—carbon, 53.21; hydrogen, 6.45; ash, .32; specific gravity, .5624. Fuel-value by weight, 4488.3; by volume, 2524.2.

For the non-coniferous woods the average results of forty-one determinations were—carbon, 49.53; hydrogen, 6.33; ash, .66; specific gravity, .6951. Fuel value by weight, 3993.9; by volume, 2776.1. These latter values agree very closely with those given in the books, as the results of the analyses of European woods. It is rather singular that with the exception of fir, no coniferous woods have been reported on in Europe.

After the long sticks of wood had become thoroughly seasoned, they were dressed out to the exact size of four centimeters square, and were sawed as near as possible to the length of 11 decimeters. They were then tested on the Watertown machine. In testing, the stick was placed in a perpendicular position resting on supports that were exactly one meter apart. The force was then applied at the centre of the length by means of an iron bearing, which had a length a little greater than the width of the stick and a radius of 12.5 millimeters. The weights were slowly applied, 50 kilograms at a time, and after each weight was added, the deflection was noted. After 200 kilograms had been added, the weights were removed and the set read; the weights were again applied, the reading again taken at 200 kilograms, and then at every 50 kilograms until the stick was broken, the breaking weight being noted. In making the report, the coefficient of elasticity for the weights 50 and 100 have been calculated; also the modulus of rupture.

So far I can only give the most general results in regard to these tests. In the first place we have not been able to establish any general law in regard to the direction in which a stick is the strongest, that is, parallel or perpendicular to the annual rings.

The results have shown, however, that it is by no means necessary to break two sticks to show which is the strongest, provided they are of the same kind of wood. The weak stick will show the largest deflections from the start. The strongest stick found was a specimen of locust, but following closely after it were specimens of hickory and Southern pine. Ash was found to stand well up to a certain point, and then it gave way suddenly and without warning, generally shattering badly. The California red-wood was another that shattered very much. White oak was found to be inferior in strength to several other oaks, and to Southern pine, the average breaking weight of 40 specimens being 386 kilograms, while the average breaking weight of 8 specimens of *Quercus prinoides* or the cow oak of the South was 528 kilograms.

The average of 27 specimens of *Pinus Australis* was 490 kilograms.

The average of 36 specimens of the Douglas fir from the Pacific coast was 374 kilograms, and of six specimens of the Western larch was 523 kilograms.

13 specimens of white pine (*Pinus Strobus*) gave 274 kilograms.

11 specimens of beech gave an average of 454 kilograms.

16 specimens of *Carya sulcata* averaged 464 kilograms.

20 specimens of white hickory (*Carya alba*) averaged 512 kilograms.

24 specimens of white ash (*Fraxinus Americana*) averaged 378 kilograms.

8 specimens of locust averaged 543 kilograms.

The next series of tests which were made, consisted in taking specimens of the same size, square as before, and 32 centimeters long, and compressing them in the direction of their fibres. Here again both locust and the Southern pine stood up well.

9 specimens of locust stood an average weight of 11,206 kilograms.

5 specimens of the Western larch stood an average of 10,660 kilograms.

35 specimens of white oak stood an average of 8183 kilograms.

24 specimens of *Pinus Australis* stood an average of 10,498 kilograms.

The third series of tests was to find the force necessary to indent the wood at right angles to the grain. These tests are not finished yet, and I have made no examination of the results. They are made on blocks 4 centimeters square and 16 centimeters long, the bearing of such a size that it makes an impression on the block, which extends from side to side of the block and is of the same length; or, in other words, is 4 centimeters square.

In closing this paper I wish to express my thanks to Col. Laidley for valuable suggestions made during the progress of the work, and to Mr. Howard for the able manner in which he has executed the tests. These tests have been made at the joint expense of the War Department and the Census Bureau, the machine having been put at our service by order of the Secretary of War.

The tests will all probably be published in the annual report of the testing machine, calculated in feet and pounds.

THE MINING REGION AROUND PRESCOTT, ARIZONA.

BY JOHN F. BLANDY, PRESCOTT, ARIZONA.

WITH the Report of Mining Statistics, for the year 1872, there was published a geological map of the United States and Territories. This is, I believe, the only map which represents the geology of Arizona, and is, as far as my observations go, correct. It is, however, on so small a scale as to be of little practical value to the miner. I know of no other maps, even of localities, of this Territory. The topographical maps are also on so small a scale as not even to serve as guides from place to place; the largest, that of Eckhoff and Ricker, being only 30 by 30 inches to represent a territory of 135,000 square miles. For these reasons, it makes it exceedingly difficult to describe the various mining centres in an intelligent manner, and equally so to examine such a hilly country as it is intended to describe in this paper.

When I first came into this Territory I soon realized the troubles I had to encounter in trying to form an opinion, or even to get the needed information on the geological contour. I have, therefore, labored as best I could to get a topographical diagram of the section of country represented by the map which accompanies this paper.*

The lines run by the Land Department up the valleys of the Aqua Frio, and those west of the Hassayampa, and connected east and west to the north of Prescott, enabled me to inclose correctly the space covered by the Bradshaw and Sierra Prieta mountain groups, but the territory covered by these mountains, and the most difficult part, I have had to fill up as best I could. I have met with such success as to meet the approbation of those most familiar with the country, and, with the map in hand, any one would be able to cross it in any direction. As there has not been a single line of survey made across it, this has been no small undertaking, and I have had to depend upon sights from prominent points with the pocket-compass, or, in the absence of that, to make observations, with watch in hand, and guess as near as possible the meridian direction. But one main wagon-road passes through the district, that from Prescott to the Peck mine.

* The engraved map accompanying this paper, is one-half the scale of the original map.—ED.

Having constructed a map with approximate correctness, it remains to mark in the general geology; but it is still difficult to draw accurately the distinct lines of junction between the formations. To do this requires an amount of muscular exertion that no one can understand unless he has tried it in such a hill-country—a region of gulches and steep, rocky hillsides, most of it covered with a growth of tangled thorny bushes, or prickly, poisonous cactus plants.

I have, therefore, only marked the general run of the rocks, without attempting the line of the boundaries of any. It is only meant as a skeleton upon which others may assist in filling in the detail as they may be able. It is the detailed geology of a region which is of the most assistance to the miner, and it cannot be too minute. I am not aware that any geological map has been issued of any locality of Arizona.

I shall refer only to that part of the map which shows the country between the Peck mine and the town of Prescott. The Peck mine is situated in a primary slate formation, the north boundary of which is at Bear Run. This sweeps around in a northerly direction, crossing Turkey Creek, and the mouth of Wolf Creek, the head of Cedar Creek, and after crossing the Big Bug Creek to the north of the Station, passes northward by the Silver Belt mine, and is lost to view under the Aqua Frio flats and Lonesome Valley, or what is marked on the government maps as the Prescott Plains.

To the north of this formation we have a porphyritic-granite ridge, passing from the Tuscumbia mine through to Trinity, crossing Turkey Creek at the mouth of Pine Creek, thence over the high divide between Pine and Wolf creeks. This does not show itself at Big Bug Creek, unless the small field of granite near Boggs be a continuation of the same. Next north of this granite ridge we have a syenitic gneiss, covering the country up to the foot of Mount Union, with the exception of a narrow belt of hornblende slate, which crosses Turkey Creek at the Masterson mill. This brings us to the great granite centre of Mount Union. From its sides start out the various streams of Main and East Hassayampa, Turkey, Big Bug, and Lynx creeks. Mount Union is said to be the highest peak, with the exception of San Francisco Mountain, in Yavapai County, which would make it about 10,000 feet above tide. It, with two neighboring peaks, one to the north, the other to the south, appears more like a north and south ridge of granite, and throws out a finger forming the dividing ridge between the Big Bug and Lynx creeks, reaching nearly to the Silver Belt mine, where it

abuts against the high-tilted slates of the first-mentioned formation. Another finger is thrown out to the southwestward, forming the divide between the East Hassayampa and Turkey Creek, the highest point of which lies between the Bodie and Bully Bueno mines. At the point where the Peck road crosses this divide, at the lowest point, it is hidden by a thin covering of the syenitic gneiss. Between Big Bug Creek and the head of Wolf Creek lies a high plateau called the "Mesa." This is a sheet of "malpais," or lava, from fifty to one hundred feet or more in thickness, which rests upon the vertical strata of the syenitic gneiss. The valley of Lynx Creek is occupied by a more or less stratified granitic rock, which extends southward across the head of Hassayampa, and beyond the Senator mine. This is separated from the large field of granite which surrounds Prescott, by the ridge of hornblende schists which crosses the Hassayampa at the bridge, and forms a divide between it and Lynx Creek, and in which heads the North Wolf, Groom, and Granite creeks, the highest point of which is Spruce Mountain.

The Prescott granite, extending northward to the great mass of Granite Mountain, here and there incloses patches of hornblende slates and syenitic gneiss, and is intersected by trap dikes, and protrusions of columnar basalt. Of the latter, two fine examples are to be seen near the town—Thumb Butte, and a hill near the mouth of Banning Creek.

To the north of Prescott on the east side of Granite Creek can be seen the syenitic gneiss which underlies the county eastward to lower Lynx Creek.

We now have a general outline of the geology of the space lying between the Peck mine and Prescott. I have seen too little of that lying to the westward or of that lying to the east of the Aqua Frio to refer to it at present.

It only remains to make some reference to the veins occurring in the various formations.

The large majority of these whether in the stratified rocks or in the granite have a northward and southward trend, varying, say, from N. 20° E., and S. 20° W. to N. 20° W., and S. 20° E. The exceptions do not vary greatly from this, though I have noticed a few that have a nearly east and west course.

Among the stratified rocks a large number are what might be called "*layer*" veins, that is, they strike and dip with the formation and are limited in length, seldom extending for more than three or four mining claims. In many instances I have supposed these to

be formed by the warping of the strata, causing openings to be made between the strata; this is particularly the case where the white quartz ledges occur, as in the belt in which are the Bully Bueno, Yaho, and the gold ledges on Pine Creek.

The veins in the slate formation of the Peck district occur in or in contact with heavy quartz strata, locally called quartz dikes, and carry silver in form of chlorides and sulphides, and in galena. In some of the veins large amounts of carbonate of iron occur. The quartz dikes are the conspicuous feature of the district, standing like high walls sometimes as much as 50 feet above the slates. The finest examples of these walls can be seen near the mouth of Wolf Creek, where they occur not more than six feet thick at the base, and stand at least 50 feet high, terminating in pinnacles,—a fair representation also of the dip of the strata.

The veins in the granite ridge next north, seem to occur in groups, as at Tuscumbia and Trinity, and on the east slope of the Wolf Creek ridge. In these the ores are also silver-bearing, in form of chlorides, with lead, brittle silver ores, and in galena and blende. The principal vein matter is quartz and barytes.

In the syenitic gneiss region the veins are all silver-bearing, with the exception of the belt referred to above, which passes through from the Bully Bueno mine across Pine and Wolf creeks, which are gold-bearing quartz veins. Between this belt and the granite on the south, the ores are much the same in nature as those of the granite, with the exception that there is but little antimony in combination. The vein stones are the same. To the north of the gold belt up to the foot of the Mount Union granite, the amount of galena in the vein increases in quantity as you go northward, until finally argentiferous galena with much pyrites is almost the only ore. The barytes also becomes less and less, and quartz increases in quantity. In this section I have found the only lime spar, in form of nail-head, that I have seen in this region. This occurs in the Goodwin vein.

The veins in the Mount Union granite are all gold-bearing, many of them also carrying silver in combination with galena, and large amounts of pyrites. The gold in the croppings of the veins and to a limited depth is free, but below is altogether in the pyrites. Some veins are found containing large amounts of carbonates of lead which yield well in silver. The decomposition of these veins and of those in Lynx Creek valley, is the source which has supplied the gold to the placers in all the streams heading in this mountain, more par-

ticularly to the Hassayampa and Lynx creeks. In some of the veins of this formation is to be found much blende of a very dark character.

The veins of Lynx Creek valley are as a rule the largest of the region, varying in width from two to twenty and thirty feet. They carry gold and silver in varying quantities. Sometimes pockets are met with yielding at the rate of several hundred dollars per ton in gold. The occurrence of silver is much more uniform. Most of these veins have been prospected largely in the cropping and the ore worked in arrastres. This has been, however, to a limited depth, I believe never over 30 feet, and most of them much less, as the baser ores occur, and the miners have had no means of treating them.

Below the decomposed croppings, the ores are the basest of the region, being a mixture in every conceivable variation of sulphurets of iron, zinc, antimony, lead, and copper. Of course, all are not equally contaminated, as in some pyrites form the mass of the ore, in others but little copper is to be seen. As a rule it may be said that the ores will average some sixty dollars per ton in the precious metals. This district is generally regarded as the gold section of the region. The prevailing vein stone is quartz and decomposed wall rock. The only rare minerals I have heard of as occurring in these veins are molybdates and phosphates of lead in the Accidental mine, but I have seen none.

The veins of the hornblende-schist range are gold and silver-bearing apparently in about equal quantities. The silver occurs as chloride, and also in galena, many very rich and large specimens of the former (hornsilver) having been found. In some of the veins very rich streaks of gold have been encountered by the prospectors. Much of the vein material is of a talcose slaty nature near the walls, and the ore streak is largely made up, in many of the veins, of a very flinty, yellowish-brown massive quartz; this is particularly the case where galena occurs in the vein. But few veins and hardly any of note have been opened in the Prescott granite. On the southern edge of it along the Hassayampa some strong veins of gold-bearing pyrites have been opened; a strong galena vein, with a small amount of pyrites and a large vein of copper pyrites, have been developed to some extent.

To this meagre description of the region I might add that a band of porphyritic slate extends on the east side of the Aqua Frio from the Homestake mine at the western foot of the Black Hills south-

ward to Copper Mountain. Whether this formation lies next east to the slates of the Peck district or not, I cannot tell, not having closely examined it. So far as examined, these porphyritic slates show veins of copper ore of high grade, containing silver in greater or less quantities from $7 to $35 per ton.

On the map I have marked approximately the sections covered with timber. This consists of pine, oak, and juniper.

The streams called creeks, for the want of a better name, might more properly be called *sluice ways* to carry off the heavy falls of water in the rainy season. There is, however, a small amount of running water in all of them for most of the year, particularly in the winter and spring, caused by the melting of the snows.

As I have said, this is but a meagre description of the geology of a large and important mineral district; but I have meant it only as a beginning, by furnishing an outline of the district and giving an opportunity for others to assist in building upon the foundation which is thus begun.

It will be understood that the mineral district extends much beyond that part which I have attempted to describe. It reaches southeastward to the Tip Top mine region, the copper deposits of Castle Creek, the Tiger district, and southwestward to the Vulture mine near Wickenburg, and the gold mine of Antelope Peak; westward to include the copper mines in Copper Basin, and on the east it covers the copper and silver mines of the Black Hills and Ash Creek, and the gold region of Cherry Creek near the Verde. To these may be added the gold mines and placers of the Black Cañon and Squaw Creek.

This region possesses as fine a climate as can be found in the United States, fine open weather in winter with but few storms and those of snow. The nights, from November to April, are cold, although the days may be clear and balmy. In summer, though the thermometer may register 105° to 110° in the shade, the atmosphere is by no means as oppressive as in the Atlantic States at 85° to 90°. There are very few days in the year when it is too disagreeable to work in the open air. Many severe things have been said of "dry Arizona," but it has never been called the "land of beautiful and glorious sunshine," to which it is entitled.

THE ANALYSIS OF FURNACE GASES.

BY MAGNUS TROILIUS, CHEMIST TO THE MIDVALE STEEL COMPANY, PHILADELPHIA.

For some time I have been using with great advantage, for the purpose of determining rapidly and accurately the chemical composition of gases from Siemens producers, an apparatus arranged generally like that proposed by Prof. Eggertz;* and I now take pleasure in laying before the members of the Institute a description of the apparatus and its use, hoping that some of them may find it of practical advantage.

At the end of the paper are given some results obtained and heat calculations, with the necessary data for the same.

COLLECTION OF GASES.

Fig. 1. Shows the arrangement for taking a sample of gas. The funnel F, which may be made of tin plate, is made to fit the test-hole. The gas passes up through the funnel and through the rubber-tubing with the glass tube K, filled with asbestos for retaining dust, and is drawn into the upper flask by means of water flowing from the same into the lower flask. The upper flask must be *completely* filled with water from the beginning, so that no air remains. When filled with gas the screw-compressors are securely fastened on, and the flask disconnected from the funnel and receiver. Quart flasks, with openings at the bottom, are very suitable, and easily obtainable.

COMPOSITION OF THE GASES.

The ingredients found in producer gases are: carbonic acid (CO_2), oxygen (O), ethylene (C_2H_4), carbonic oxide (CO), hydrogen (H), and marsh gas (CH_4). The nitrogen is taken by difference. CO_2,O,C_2H_4, and CO are determined by absorption in various liquids and by observing the resulting diminution of volume. H and CH_4 are determined by combustion with oxygen.

Carbonic acid.—For this gas is used a solution of 16 grams of potassium hydrate in 100 c.c. of water. 4 or 5 c.c. of this solution absorb 100 c.c. of CO_2.

* Jernkontorets Annaler, 1882.

Oxygen.—20 grams of pyrogallic acid are dissolved in 100 c.c. of air-free water. For use, this is mixed with an equal volume of the above potassium hydrate solution. 4 c.c. of the mixture absorb the oxygen from 100 c.c. of air. It should be kept in a dark bottle.

GAS COLLECTOR
Scale, 1½″=12″

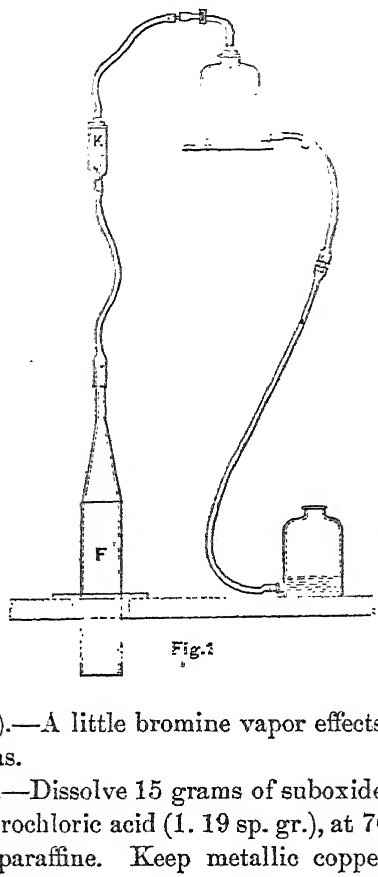


Fig. 1

Ethylene (C_2H_4).—A little bromine vapor effects the complete absorption of this gas.

Carbonic oxide.—Dissolve 15 grams of suboxide of copper (Cu_2O) in 100 c.c. of hydrochloric acid (1. 19 sp. gr.), at 70° or 80°C. under a thin layer of paraffine. Keep metallic copper in the solution and use a dark bottle.

Hydrogen and Marsh gas (CH_4).—Fig. 2 shows the combustion-tube, through which the mixture of these gases is passed. It is of platinum, with .5 mm. internal and 2 mm. external diameter. At the ends it is provided with cylinders of German silver for attaching rubber-tubing. Mr. J. Bishop, of Sugartown, Chester County, Pa., supplies good tubes of this kind.

As seen from the sketch the tube is bent into a double coil, and in use it is held in a slanting position, the smaller coil only being heated to redness during the operation. Very rapid combustion takes place

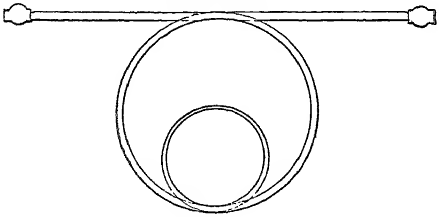


Fig.2

in this way. The bore of the tube should not be above .5 mm., otherwise explosions can occur.

COMPLETE ANALYSIS.

Fig. 3 shows the apparatus for complete gas analysis. The gas burette B is graduated to 100 c.c. capacity. It is connected with the funnel at the top, by means of a three-way stopcock, which can be turned so as to communicate with either the funnel or the pipette P, of 200 c.c. capacity. Between the pipette and the burette the combustion-tube is suspended. A screw-compressor is applied between the combustion-tube and the three-way stopcock; this compressor is used, during the combustion, as the chief regulator of speed for the gas mixture passing from B to P and returning to B. The flasks F and F′ can be raised or lowered by means of the stands S and S′, with movable shelves or brackets, as shown.

At the lower end of the burette an ordinary glass stopcock is placed; a three-way stopcock would, however, also work very well here, as it is necessary, during the operation, to connect alternately with a suction-pump and the flask F. Before reading off the volume, the gas is compressed a few centimeters by raising the flask F, and letting it bubble up through a little water in the funnel. In this way the gas is made to assume the same pressure as the air. The volume may now be taken either by holding F so that the water therein is on the same level as the water in the burette, or simply by letting in water from the funnel as long as it will run. I prefer the former mode. The cylinder C is filled with water and holds a Centigrade thermometer. The temperature can thus be observed and kept constant during the entire analysis. This is of impor-

tance in accurate work, as the gas expands according to the formula $v\ (1 + .004t^{\circ})$, or about .4 c.c. for every degree Centigrade.

To start an analysis, draw out a few cubic centimeters of water by means of the suction pump, taking care to have the screw-compressor

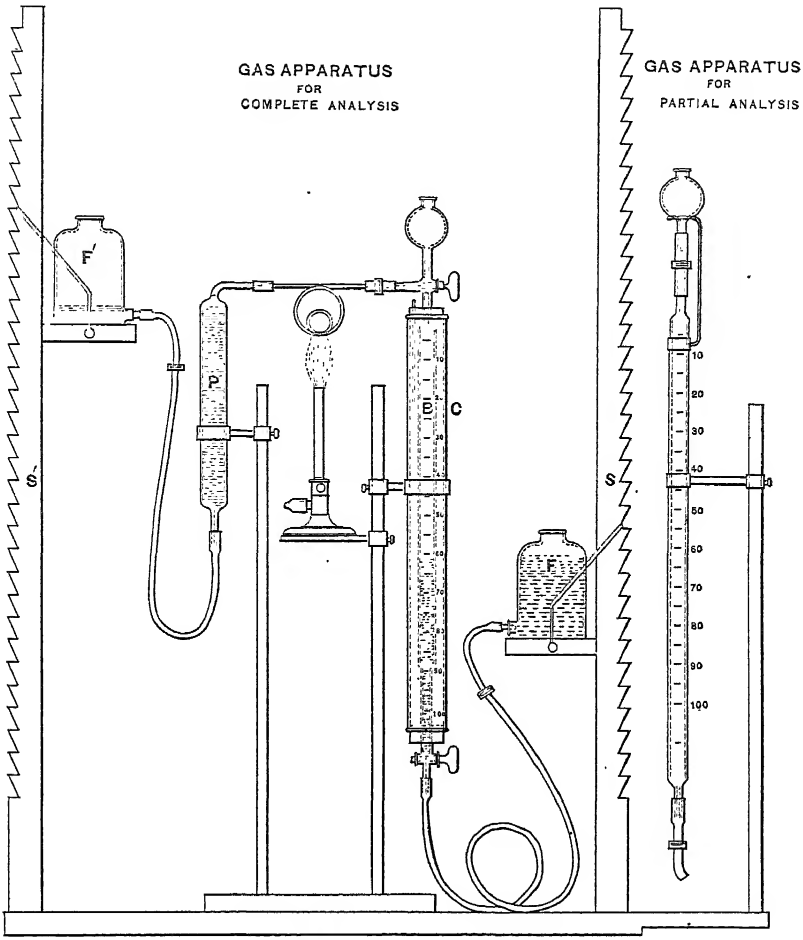


Fig.3 Scale, 1½″=12″ Fig.4

at the top well closed, and the funnel shut off, when the lower stopcock is open. Let a few cubic centimeters of the potassium hydrate solution flow into the burette from the funnel. Almost all the carbonic acid is taken up when the alkaline liquid flows down slowly along the sides of the burette. It is well, however, to take out the burette from the holder and move it so as to let the liquid flow slowly

backwards and forwards. The potassium hydrate is then carefully washed out by repeatedly drawing off the liquid from the bottom of the burette by means of the suction-pump, and letting pure water flow in from the top of burette; the remaining volume of gas is then read off. The other gases are then taken in the same way, by introducing the proper absorbent, observing that in the case of ethylene no shaking of the burette is required, as the bromine vapors fill the burette.

Each reagent must be carefully washed out before introducing another, and they must be used in the order described, namely: potassium hydrate for carbonic acid, pyrogallic acid for oxygen, bromine for ethylene, subchloride of copper for carbonic oxide. A little hydrochloric acid must be added to the first water used for washing out the last-named reagent, as otherwise a white precipitate of basic copper chloride will come down.

Potassium hydrate would expel carbonic oxide from its solution in subchloride of copper. Both hydrochloric acid and bromine give a tension to the gas; but this is obviated by careful washing before reading off. More shaking is required to effect the absorption of the carbonic oxide than in the case of the other gases.

The absorbing influence of water does not practically interfere with the results, if the gas is analyzed soon after taking the sample. If the gas be allowed to stand in contact with water for any length of time, the carbonic acid will be partly or wholly absorbed, while the other gases suffer but very slight diminution in volume.

After removing the carbonic acid, oxygen, ethylene and carbonic oxide, as above described, about 20 c.c. of pure oxygen are taken in to the pipette P. This is an ample quantity for determining by combustion the amounts of hydrogen and marsh gas, usually contained in about 100 c.c. of producer-gases. As a safeguard against explosions, the rule may be observed, that *the sum of the volumes of the gases taking part in the combustion, must not exceed one-half of the total volume of the gases in the burette.*

To mix the gases in the burette with oxygen, the flasks F and F′ are raised and lowered alternately, and the speed of flow of gas regulated by means of the screw-compressor at the top of burette. When thus mixed the volume of the gas mixture is read off and the combustion-tube gently heated while the gas is passed at the rate of about 10 c.c. per minute from B to P. The smaller platinum coil is then heated to full redness and the gases are drawn back from P to B. Complete combustion of hydrogen and marsh gases then takes place in the tube; vapor of water, which condenses, and carbonic

acid are formed; one volume of hydrogen giving one volume of water, and one volume of marsh gas giving one volume of carbonic acid and two volumes of water.

The actual number of cubic centimeters representing the *free* hydrogen in the original gas volume, is consequently obtained from the formula:

$$\tfrac{2}{3}\ [\text{M}—2\text{c.}]$$

M being the total diminution of volume after combustion, and *c* the volume of the carbonic acid from the marsh gas. This carbonic acid is of course determined as previously described. It gives the volume of the marsh gas direct.

Fig. 4 shows a simpler burette without glass stopcocks, chiefly intended for the determination of carbonic acid, oxygen, and carbonic oxide only. By inserting a T tube between the funnel and burette, a more extended use may be had of this very simple and convenient apparatus. In this case, however, bromine cannot be used for the ethylene, as it would attack the rubber-tubing. Sulphuric acid, in a special burette, and before using the other reagents, could be used instead. Producer-gases do not, as a rule, however, contain any considerable amounts of ethylene or oxygen, and for practical purposes these gases may be left out of the analyses altogether.

ANALYSES AND CALCULATIONS OF HEAT.

In a special table below are given the results of nine analyses of producer-gases by the method described. The first six samples were taken from the blast-producers of Messrs. Hoopes & Townsend, of Philadelphia. These producers were designed by their mechanical engineer, Mr. Ferdinand Philips. Sample No. 1 was taken from a producer into which the blast was forced by means of a fan; in all the other cases the blast was forced in by means of steam-injectors. Anthracite coal was used in all the producers.

The last three analyses in the table were taken from the Siemens draught-producers for the open hearth-plant at the Midvale Steel Works, using soft coal.

To find the total amount of heat-units that can be developed by the complete combustion of 100 liters of one of the gases at 0° C., and 760 mm. pressure, one has only to multiply the CO, C_2H_4, H, and C_2H_4, as found from the table, by the number of heat-units belonging to each of these gases per one liter at 0°C. and 760 mm. pressure. These numbers are, according to Bunsen:

For hydrogen, 3088 (burned to H_2O, which condenses).
For carbonic oxide, 3007.
For marsh gas, 8482.
For ethylene, 13982.

One volume of hydrogen requires for combustion to one volume of water, one-half its volume of oxygen ($2\frac{1}{2}$ vol. of air).

One volume of carbonic oxide requires for its combustion to one volume of carbonic acid, one-half its volume of oxygen ($2\frac{1}{2}$ vol. of air).

One volume of marsh gas requires two volumes of oxygen (10 vol. of air) for its combustion, to one volume of carbonic acid and two volumes of water.

One volume of ethylene requires for its combustion to two volumes of carbonic acid and two volumes of water, three volumes of oxygen (15 vol. of air).

These four combustions are chemically expressed thus:

Hydrogen.

$$\frac{2H}{2\text{ vol.}} + \frac{O}{1\text{ vol.}} = \frac{H_2O.}{2\text{ vol.}}$$

Carbonic Oxide.

$$\frac{CO}{2\text{ vol.}} + \frac{O}{1\text{ vol.}} = \frac{CO_2.}{2\text{ vol.}}$$

Marsh Gas.

$$\frac{CH_4}{2\text{ vol.}} + \frac{4O}{4\text{ vol.}} = \frac{CO_2}{2\text{ vol.}} + \frac{2H_2O.}{4\text{ vol.}}$$

Ethylene.

$$\frac{C_2H_4}{2\text{ vol.}} + \frac{6O}{6\text{ vol.}} = \frac{2CO_2}{4\text{ vol.}} + \frac{2H_2O.}{4\text{ vol.}}$$

The latent heat of vapor of water per liter is (Bunsen) 514 heat units. The specific heat, per liter, at 0° and 760 mm. pressure of nitrogen, carbonic acid, and vapor of water are (Bunsen):

For nitrogen	—	.307
" carbonic acid	—	.425
" vapor of water	—	.382

By aid of these data the theoretical or flame temperatures of the

gases are calculated. In these calculations it is supposed that the gas is completely consumed with the least possible amount of air, and that the heat is entirely taken up by the products of combustion, viz.: carbonic acid, vapor of water, and the nitrogen, which was partly present in the gas before combustion, and partly carried along with the air for combustion.

The calculation of the flame temperature is best illustrated by an example. Take, for instance, gas No. 1 *a* (vide table). We have:

$$93966 = [(3.9 + 27.3 + 1.4)\ .425 + (67.4 + 54.6 + 11.2)\ .307]\ T \\ + 514 \times 2.8 + (T - 100)\ 2.8 \times .382.$$

This equation may be transformed thus:

$$93966 - (476 \times 2.8) = [(3.9 + 27.3 + 1.4)\ .425 \\ + (67.4 + 54.6 + 11.2)\ .307 + (2.8 \times .382)]\ T \\ \therefore T = 1619°\ C.$$

This latter equation gives a good general rule for calculating the flame temperature of a gas as follows:

Put the number of calories per 100 liters, minus 476 times the volume of the water formed by combustion of 100 liters, equal to the temperature sought, multiplied by an expression consisting of a sum obtained by multiplying the CO_2, H_2O, and N with their respective specific heats per liter and adding the products together.

	HOOPES & TOWNSEND. PHILIPS PRODUCER.						MIDVALE. SIEMENS PRODUCER.		
Notes. 1*a*. and 1*b*., from different producers but at the same time. 2*a*. and 2*b*., do. 3*a*. and 3*b*., from the same producer. The last two analyses from Midvale belong together, being taken with ½-hour interval.	No. 1*a*. Fan-blast. Hot-working producer.	No. 1*b*. Steam-blast. Cold-working producer.	No. 2*a*. Steam-blast. Just before cleaning producer. Bad coal.	No. 2*b*. Steam-blast. Bad coal.	No. 3*a*. Steam-blast. Normal running.	No. 3*b*. Taken 10 minutes after sample 3*a*, with air shut off as far as possible and only steam let on.	Sample taken just after cooling down fires with water from below.	Sample taken just before cooling fires with water.	Sample taken just after cooling down fires with water from below.
Carbonic acid CO_2	3.9	8.7	9.3	7.5	8.0	6.1	5.7	1.5	5.9
Ethylene, C_2H_4 .							.9		
Carbonic oxide, CO, ...	27.3	20.0	16.5	16.0	15.5	22.3	15.4	23.6	17.7
Hydrogen, H, .		8.7	8.6	15.3	14.9	28.7	8.3	6.0	9.8
Marsh Gas, CH_4	1.4	1.2	2.7	1.9		1.0	3.8	3.0	2.4
Nitrogen, (difference) N, . .	67.4	61.4	62.9	59.3	61.6	41.9	65.9	65.9	64.2
Total, . . .	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Calories pr. 100 liters at 0° and 760 mm. . .	93966	97184	99074	111474	92620	164164	116753	114939	103843
Flame-temperature, ...	1619°	1658°	1575°	1706°	1613°	1846°	1656°	1761°	1642°

THE DETERMINATION OF COPPER IN STEEL.

BY MAGNUS TROILIUS, CHEMIST TO THE MIDVALE STEEL COMPANY PHILADELPHIA.

THE following is a very rapid method for determining copper in steel. I have found it to give results very closely agreeing with those obtained by galvanic precipitation of the copper.

Five grams of steel are dissolved in a mixture of 100 c.c. of water and 10 c.c. of sulphuric acid. When all is dissolved, add 2 c.c.

of a concentrated solution of thiosulphite of soda ($Na_2S_2O_35H_2O$) and stir well. After 15 minutes boiling, all the copper is down as black subsulphide of copper (Cu_2S) and the solution regains its greenish color. Filter rapidly, wash a few times with hot water, pierce the filter, and wash the precipitate back into the beaker, in which it was made.

Dissolve in a little aqua regia and evaporate with about 2 c.c. of sulphuric acid, until white fumes appear. Dilute with water, heat to near boiling and add excess of ammonia (sp.gr. 0.96). Allow to settle in a warm place, filter and wash with hot water containing some ammonia. From the filtrate evaporate the excess of ammonia, add a little dilute sulphuric acid till it is slightly acid, and precipitate the copper as before with a few drops of hyposulphite of soda. Filter on a washed filter-paper, wash with hot water, place the wet filter in a weighed porcelain crucible, ignite and weigh as oxide of copper (CuO).

When an ordinary Bunsen burner is used, care should be taken not to let the crucible come into contact with the inner cone of the flame.

WATER-GAS AS FUEL.

BY W. A. GOODYEAR, M. E., NEW HAVEN, CONN.

It is safe to assert that in cities generally, the fuel of the future for all domestic, as well as for most manufacturing and metallurgical purposes, will be gaseous fuel. The immense advantages which gas possesses in facility and cheapness of distribution, cleanliness, and economy of manipulation, and the facilities which it offers for utilizing in almost all cases a much higher percentage of the total quantity of heat produced, than it is possible to do with any kind of solid fuel, are facts which will vastly more than compensate for the comparatively small loss of heating power, which will be found necessary in the turning of the solid fuel into gas upon a large scale, and which, in the opinion of the writer, will, at no distant day, command attention, and will ultimately result in a revolution in our use of fuel.

The employment of gaseous fuel upon a scale of any considerable magnitude, has hitherto been almost entirely confined to the utilization of the waste gases of the iron smelting furnace for heating the blast, and the rapidly increasing use, for certain metallurgical pur-

poses, of Siemens-generator gases. By means of the latter, it become possible, in many localities, to utilize solid fuel of so poor a quality as to be utterly unfit for direct application to metallurgical purposes, while the gas which it furnishes is easy of application, and is capable of producing, without difficulty, the highest degrees of heat ever required in such operations. But as a fuel for general application to domestic and manufacturing purposes, the Siemens-generator gas has two great drawbacks: First, the total quantity of heat which it is capable of producing for a given volume of gas, is quite small in comparison with what can be obtained from some other gases, while, if the comparison were made between equal weights instead of equal volumes, the difference would be greater still, for the Siemens gas is a gas of high specific gravity. Second, this gas always contains a very large percentage of nitrogen, together with smaller quantities of some other gases, which not only add nothing to its heating power, but carry off a considerable percentage of the heat actually produced by the combustible ingredients.

The latest experiments on a scale of some magnitude in our cities, in the way of heating buildings and furnishing power for manufacturing purposes, have been by the distribution of high pressure steam through pipes laid in the streets. But these experiments have not hitherto been very successful; and when we consider the high cost, and the great and unavoidable loss of heat and power, which always accompany the conveyance of high pressure steam to any considerable distance in pipes, to say nothing of certain practical difficulties in the management of the pipes themselves, it is evident that all such methods must eventually disappear before a system which can furnish a cheap gas of great heating power, easily distributed wherever wanted, without requiring pipes to stand pressures of 50 to 75 lbs. per square inch, and without keeping the whole mass of ground in the streets through which it passes, hot, *gratis*, for a distance of ten or fifteen feet in all directions around the pipes.

The gas which best answers all the most important requisites for a good gaseous fuel, is "water-gas," consisting essentially of a mixture of equal volumes of carbonic oxide and free hydrogen, obtained from the decomposition of steam by contact with incandescent carbon.

Much experimenting has been done under various patents within the last few years, in the way of attempts to produce a cheap and good illuminating gas, by the enriching of water-gas with the vapors of the various heavy hydrocarbons, and these experiments have been attended with a certain degree of success. But it seems somewhat

remarkable that while so much ingenuity and money have been expended in that direction, the far easier adaptability of water-gas as a means for the cheap and convenient production of heat, and the immensely greater field which is open for its application to this purpose, have been, comparatively speaking, almost entirely neglected.

The chief cause of this neglect lies probably in the fact, that hitherto no method has been generally known by means of which water-gas could be produced at so low a cost and in such large quantities as are required for a fuel gas. There is good reason to believe, however, that an apparatus devised by the writer will supply this lack, and that water-gas can now be made in any quantities that may be desired, and at a cost that, besides leaving a handsome profit for the manufacturers, will render its general use in cities far more economical than that of any kind of solid fuel.

In support of this assertion, I propose to present first, a short outline sketch of the most prominent features of the apparatus referred to, and its general method of working; second, some theoretical considerations, with reference to the absolute heating power and maximum flame temperature of water-gas, as compared with those of ordinary illuminating gas, and the gas from Siemens generators; and third, a few resulting inferences and general remarks.

The apparatus itself consists of a generator, in combination with regenerative or superheating chambers and proper pipe connections, to carry out the process.

In the accompanying drawings, Fig. 1 is a vertical longitudinal section of the apparatus, showing the generator, with two sets of regenerative chambers and the necessary pipes, valves, etc.

Fig. 2 is a vertical section through the generator, on the line V W of Fig. 1, on a plane at right angles to that of Fig. 1. Fig. 3 is a horizontal section through the bottom of the generator, showing ash-boxes, etc.

A represents the generator, which is lined with firebrick and filled with fuel which is ignited. This fuel may consist of coal, coke, or other suitable carbonaceous material.

B and B′ are the two sets of regenerative chambers, lined throughout with fire-brick. The separate regenerative chambers are filled with loosely piled firebrick, as shown. The partition walls C C′ between these chambers are constructed of firebrick, and are made as nearly as possible air-tight. Passages D D′ are formed alternately at the bottom of one partition and top of the next one, in order to compel the gases in traversing the set to pass down one

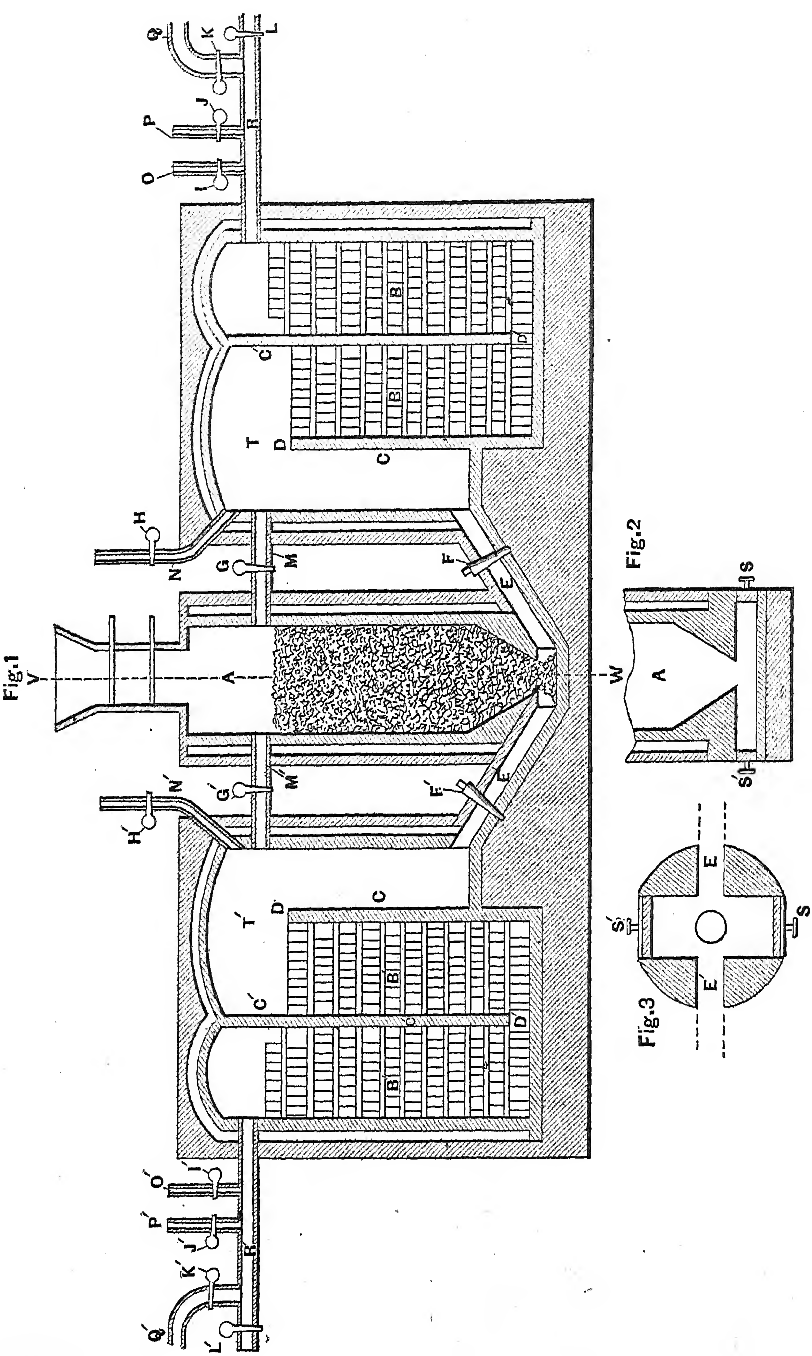


Fig. 1

Fig. 2

Fig. 3

chamber and up the next throughout the set without reference to the number of separate chambers used.

The two flues E E′ lead from the bottom of the nearest regenerators on either side into the bottom of the generator A. Through these flues the blast of air or steam reaches the fuel. F F′ are valves in these flues, which may be opened or closed, so as to control the blast from either direction at will. G G′ are valves in the pipes M M′. H H′ are valves in the pipes N N′. I I′ are valves in the pipes O O′. J J′ are valves in the pipes P P′. K K′ are valves in the pipes Q Q′. L L′ are valves in the pipes R R′, all of which can be opened or closed at will, and the use of which will be more clearly explained hereafter.

The generator A is provided with a charging-funnel at the top, provided with dampers, as shown. S S′ are ash-pit doors closing the apertures, through which the ashes, etc., may be raked out.

The process of manufacture is as follows: A blast of air from a blowing-engine or other apparatus is introduced through the pipe O. The valves L in pipe R, K in pipe Q, J in pipe P, G in pipe M, H in pipe N, F′ in flue E′, I′ in pipe O′, J′ in pipe P′ and K′ in pipe Q′ are closed; and valve I in pipe O, F in flue E, G′ in pipe M′, H′ in pipe N′ and L′ in pipe R′ are open. The air so introduced passes on through the regenerators B, under and above the partitions C into the chamber T, and then enters the generator A through the flue E.

In passing up through the mass of incandescent fuel in the generator its oxygen takes up an equivalent of carbon and forms carbonic oxide, and the gas issuing from the top of the fuel consists, essentially, of nitrogen and carbonic oxide, together with such volatile hydrocarbons as the fuel may have yielded. This gas, being formed by the action of air upon the fuel, I shall denominate "air-gas," in order to distinguish it from the water-gas, which is formed in the second stage of the process.

The air-gas, issuing from the generator through the pipe, M′, into the room or chamber, T′, is there met by a second blast of air, introduced through the pipe, N′, the valve H′ being open, whereby it is burned, producing a high degree of heat. The intensely heated products of this combustion pass on through the regenerative chambers, B′, yielding up on the way most of their heat to the firebrick, with which these regenerative chambers are filled, and, issuing at last in a comparatively cool condition, are conveyed through the pipe, R′, to a chimney, where they are discharged.

When this operation has been continued for a sufficient length of time, so that the firebrick in the regenerative chambers, B′, nearest the generator have attained an intense heat, the valve, I, in the pipe, O, is closed, thus shutting off the blast of air. The valves are now changed as follows: K in pipe Q, G in pipe M, F′ in flue E′ are open; and valve F in flue E, G′ in pipe M′, H′ in pipe N′ and L′ in pipe R′ are closed. The valve, J′, in the pipe, P′, is then opened and a jet of steam is introduced through the pipe, P′. This steam, passing through the regenerative chambers, B′, becomes intensely superheated, and in that condition enters the bottom of the generator through the flue, E′. In passing up through the incandescent fuel in the generator it is decomposed, with the formation of carbonic oxide and free hydrogen, and the mixture of these two gases, with such volatile hydrocarbons as the fuel may furnish, which now issues from the top of the fuel in the generator, constitutes the water-gas, which it is the object of the process to produce. The water-gas thus formed, issuing from the generator through the pipe, M, passes on through the chambers, B B, where it leaves most of its heat, and entering the pipe, R, is conducted thence by the pipe, Q, to the purifying apparatus, if such be employed, and thence to the gas-holder, where it is stored for use.

As the production of water-gas involves the absorption of a large amount of sensible heat, it is accompanied by a rapid decrease of temperature in the chambers, B′, and eventually also in the generator, A, while at the same time the chambers, B, are only moderately heated by the sensible heat of the current of gas produced. As soon as this cooling process has proceeded so far that the temperature in the generator, A, is no longer sufficiently high to enable the fuel to decompose the steam with facility, the valve, J′, in the pipe, P′, is closed, shutting off the steam, and the valves, L, in pipe R, and H, in pipe N, are opened, and the valve, K, in the pipe, Q, is closed. Then the valve, I′, is opened and a blast of air is introduced through the pipe, O′. This air traversing the chambers, B′, and the room, T′, becomes considerably heated on the way by the heat which still remains in those chambers, and thus heated it enters through the flue, E′, into the bottom of the generator. The air-gas, which now issues from the pipe, M, into the room, T, is here met by another blast of air from the pipe, N, and so burned. The resulting products of this combustion pass on through the chambers, B, and through the pipe, R, to the chimney, where they are discharged. The temperature now rapidly falls in the chambers, B′, and rapidly

rises in the generator, A, while the chambers, B, speedily become heated to the same intense degree which was at first produced in the chambers, B′. As soon as the desired temperature is reached in the generator, A, and the chambers, B, the valve, I′, in the pipe, O′, is closed, shutting off the blast of air, and valves F′ in flue E′, G in pipe M, H in pipe N, and L in pipe R are closed; and G′ in pipe M′, F in flue E, J in pipe P, and K′ in pipe Q′ are opened. A blast of steam then enters the apparatus through the pipe P, and, passing through the chambers B, enters the generator through the flue E. The resulting gas, passing out of the generator, through the pipe M′, chambers T′ and B′, and pipe R′, is conducted by the pipe Q′ to the gas-holder, where it is stored.

When the chambers B and the generator A have again become cooled so far that the fuel no longer decomposes the steam with facility, the valves are again changed, so as to shut off the steam and send a blast of air through the apparatus in the same direction last followed by the steam, which rapidly raises the temperature in the generator, A, while at the same time the combustion of the air-gas produced speedily reheats the chambers, B′, the cooled products of this combustion being discharged by the chimney, as before. Then the valves are again changed, so as to send a blast of steam through the apparatus in a contrary direction to that last followed by the air, and again produce water-gas, which is sent to the gas-holder, as before. Thus the process of manufacture is continued without intermission, each blast of air following the same direction through the apparatus—from right to left, or left to right, as the case may be—as the last preceding blast of steam, while each blast of steam follows a contrary direction to that of the last preceding blast of air.

While at the first glance the apparatus above described may appear somewhat complex, a very little study will suffice to show that not only the apparatus itself, but also its method of working, are in reality extremely simple, and that they possess the two all-important requisites of saving and utilizing the highest possible percentage of all the heat developed in the course of the manufacture, and of yielding, as their final products, a gas which is uncontaminated by any considerable quantities of nitrogen or other inert and injurious diluents.

As a basis for theoretical computation, assume the following data:

A.—Specific Gravities.

Air,	1.00000
Nitrogen,	0.96978
Oxygen,	1.10832
Steam,	0.62343
Hydrogen,	0.06927
Carbonic oxide,	0.96978
Carbonic acid,	1.52394

1 cubic foot of air at 0° C. and 0.76 m. pressure, weighs 0.0807561 lb. av. Or 1 lb. av. of air at 0° C. and 0.76 m. pressure, measures 12.38297 cubic feet.

B.—Specific Heats for Equal Weights.

Nitrogen,	0.2438
Steam,	0.4805
Oxygen,	0.2175
Hydrogen,	3.4090
Carbonic oxide,	0.2450
Carbonic acid,	0.2163
Air,	0.23744

C.—Calorific Powers.—*Centigrade.*

Carbon, burned to carbonic oxide,	2,473.
" " " " acid,	8,080.
Carbonic oxide, burned to carbonic acid,	2,403.
Hydrogen, burned to steam,	29,638.
" " " water,	34,462.

The latent heat of steam = 536° C.

The *calorie* used in what follows is = to 1 lb. av. of water, heated 1° C.

It follows from the above that air, consisting of nitrogen and oxygen, has the following composition:

	By Weight.	By Volume.
Nitrogen,	75.8242 per cent., or	78.187 per cent.
Oxygen,	24.1758 " "	21.813 "

Also, that 1 lb. of carbon, in decomposing $1\frac{1}{2}$ lbs. of steam with the production of equal volumes of hydrogen and carbonic oxide, will absorb $2466\frac{2}{3}$ calories.

Now take 2000 lbs. of anthracite coal, and suppose it to consist of 94 per cent. carbon and 6 per cent. ash.

For the production of steam to drive a blowing-engine allow 5 per cent. = 100 lbs. of coal; and for the production of the steam required

for decomposition assume that 1 lb. of anthracite will evaporate 8 lbs. of water.

To decompose 8 lbs. of steam, with the production of equal volumes of hydrogen and carbonic oxide there will be required $5\frac{1}{3}$ lbs. of carbon, or 5.673759 lbs. of anthracite, containing 94 per cent. of carbon. But in effecting this decomposition there are absorbed $13{,}155\frac{5}{9}$ calories, which, to produce them, will require $1.\dot{6}28\dot{1}$ lbs. of carbon, burned to carbonic acid.

Suppose, furthermore, that all the waste gases, consisting of carbonic acid and nitrogen, and all the useful gases, consisting of carbonic oxide and hydrogen, are finally discharged from the apparatus with a temperature of 200° C. In order to ascertain how much additional carbon it is necessary to burn to carbonic acid to furnish this amount of lost heat, we have the following considerations:

$5\frac{1}{3}$ lbs. of carbon in decomposing 8 lbs. of steam produce $12\frac{4}{9}$ lbs. carbonic oxide and $\frac{8}{9}$ lb. of hydrogen. Also, $1.\dot{6}28\dot{1}$ lbs. of carbon in burning to carbonic acid will require 17.959148 lbs. of air, and will produce 5.96993 lbs. of carbonic acid and 13.61738 lbs. of nitrogen. These four products, viz.: $12\frac{4}{9}$ lbs. carbonic oxide, $\frac{8}{9}$ lb. hydrogen, 5.96993 lbs. carbonic acid, and 13.61738 lbs. nitrogen, will require, in order to raise their temperature 200° C., the quantity of 2138.065 calories. The additional coal to be burned to carbonic acid must, therefore, furnish this amount of heat and also the further additional quantity required to raise the temperature of its own products of combustion to the same degree. But one pound of carbon, burned in air to carbonic acid, produces $3\frac{2}{3}$ lbs. carbonic acid and 8.36365 lbs. nitrogen, which, in order to raise their temperature 200° C., require 566.432 calories, while the combustion of the pound of carbon produces 8080 calories.

Therefore, if x represent the additional carbon, which must be burned to carbonic acid in order to permit all the above products to carry off 200° C. of heat, then to determine x, we have the following equation:

$$566.432\ x + 2138.06 = 8080.\ x$$
$$\text{whence, } x = 0.28456 \text{ lb.}$$

If, now, x be added to the quantity of carbon burned to carbonic acid, in order to furnish the heat which is afterward absorbed in the decomposition of the steam, we have for the total quantity of carbon which must be burned to carbonic acid to effect the decomposition of the 8 lbs. of steam, allowing all the products to carry off 200° C.

of sensible heat, 1.91272 lbs., equivalent to 2.03481 lbs. of anthracite, containing 94 per cent. of carbon.

The total quantity of coal, therefore, consumed in the decomposition of 8 lbs. steam (exclusive of a small portion of the 100 lbs. originally allowed out of the 2000 lbs. to drive a blowing-engine), and allowing all the products to leave the apparatus at a temperature 200° C. (*i. e.*, 360° F.) higher than they enter it, is distributed as follows:

	Lbs.
Coal burned to turn 8 lbs. of water into steam,	1.00000
" " to carbonic acid,	2.03481
" consumed in decomposing steam,	5.67376
Total,	8.70857

Now these three quantities represent the exact *ratios* to each other of the three parts into which the 1900 lbs. of coal must be divided. Taking them, therefore, in connection with the 100 lbs. at first set aside for driving a blowing-engine, we finally have the complete distribution of the whole 2000 lbs. of anthracite as follows:

	Lbs. Coal.		Lbs. Carbon.		Lbs. Ash.
To drive blowing engine,	100.0000	=	94.0000	+	6.0000
To produce steam for decomposition,	218.1759	=	205.0853	+	13.0906
Burnt to carbonic acid in apparatus,	443.9465	=	417.3097	+	26.6368
Directly used in decomposing steam,	1237.8776	=	1163.6050	+	74.2726
Total,	2000.0000	=	1880.0000	+	120.0000

	Lbs.	Lbs.		Cu. Ft.
Quantity of air used,	O. = 1112.8259 N. = 3490.2338	4603.0597	=	57,000.
Quantity of steam decomposed,		1745.4075	=	34,668.

Products.

		Lbs.		Cu. Ft.
Waste gas,	Carbonic acid,	1530.1356	=	12,433.
	Nitrogen,	3490.2338	=	44,566.
Useful gas,	Hydrogen,	193.9342	=	34,668.
	Carbonic oxide,	2715.0783	=	34,668.

Heat Carried Off.

By 1530.1356 lbs. carbonic acid, @ 200° C. =	66,193 calories.
By 3490.2338 " nitrogen, " " =	170,183 "
By 193.9342 " hydrogen, " " =	132,224 "
By 2715.0783 " carbonic oxide, " " =	133,038 "
Total carried off by gases, =	501,638 "

If to the 501,638 calories carried off by the gases we add the amount of heat absorbed in the decomposition of 1745.4075 lbs. of steam, viz.: 2,870,225 calories, we obtain 3,371,863 calories, which is the quantity of heat produced by burning 417.3097 lbs. of carbon to carbonic acid. The 2,870,225 calories absorbed in the decomposition of the steam are of course not lost, but are, as it were, stored up in the mixed hydrogen and carbonic oxide gases, to be given out again whenever they are burned. Further—

Lbs.	Cu. Ft.			
193.9342 =	34,668 hydrogen, burned to steam,	will produce	5,747,822	calories.
2715.0783 =	34,668 carb. oxide, " " carb. acid,	" "	6,524,333	"
			12,272,155	"

Thus, 69,336 cubic feet of mixed gases, derived from 2000 lbs. of anthracite, and consisting of equal volumes of hydrogen and carbonic oxide, will produce by their combustion 12,272,155 calories, which is about 81 per cent. of 15,190,400 calories, the latter being the total heat-producing power of the 1880 lbs. of carbon contained in the 2000 lbs. of anthracite.

If the apparatus in which the gases are burned is so constructed as to condense the steam produced by the combustion of the hydrogen, then (since the latent heat of steam is 536° C.) there will be saved from that source the additional quantity of 935,538 calories, making a total of 13,207,693 calories, or about 87 per cent. of the total heat-producing power of the coal.

To compute the maximum flame temperature take 1 lb. of hydrogen and 14 lbs. of carbonic oxide, being equal volumes. For their combustion to steam and carbonic acid these gases will require 66.1815 lbs. of air, consisting of 16 lbs. of oxygen and 50.1815 lbs. of nitrogen, and to heat the products of their combustion one degree Centigrade will require the following amounts of heat:

9.	lbs. of steam	will take, ...	4.3245	calories.
2.	" " carbonic acid	" "	4.7586	"
50.1815	" " nitrogen,	" "	12.2342	"
	Total,	. . . .	21.3173	"

But in combustion

1. lb. of hydrogen,	burned to steam,	produces, .	29,638	calories.
14. lbs. of carbonic oxide	" " carbonic acid,	" .	33,642	"
Total,	. . . .		63,280	"

Therefore, the maximum flame temperature = 63,280 ÷ 21.3173 = 2968.5° C., or 5375° F.

Now in order to institute a comparison between water-gas, ordinary illuminating gas, and Siemens-generator gas, I will consider, in succession, 100 cubic feet of each of these three sorts of gas, giving in each case the specific gravity of the gas, its composition, and weight, the composition and weight of the products of its complete combustion in air, the number of calories produced by such combustion, and the maximum flame temperature, all computed from data herein assumed, so that any one so disposed may judge of the data and verify the computation at his leisure.

No. 1.—Water Gas—100 Cubic Feet.

Specific gravity,			0.5195
Weight,	Hydrogen,	0.2797 lbs.	4.1955 lbs.
	Carb. oxide,	3.9158 "	
Products of complete combustion in air,	Steam,	2.5173 "	22.7065 "
	Carb. acid,	6.1534 "	
	Nitrogen,	14.0358 "	

Calories produced by complete combustion in air, 17,699.
Maximum flame temperature = 2968.5° C., or 5375° F.

No. 2.—Illuminating Gas.—100 Cubic Feet.

The composition of illuminating gas varies greatly, and no such thing as an exact average of its composition or quality can be said to exist. It is necessary, however, to assume some definite composition, as a basis upon which to found a computation. The composition which I shall assume as representing a fair ordinary quality of illuminating gas is the mean of three analyses of gases manufactured by three different companies in the city of London, as given in *Ure's Dictionary*, 7th edition, 1875. This mean, stated in volumetric percentages, is as follows:

Illuminating hydrocarbons,	3.59
Marsh gas,	37.07
Hydrogen,	48.06
Carbonic oxide,	8.12
Carbonic acid,	0.19
Nitrogen,	2.40
Oxygen,	0.57
	100.00

It will be noticed that in this analysis the heavy hydrocarbons (of which there is quite a variety) which impart to the gas its illuminating power, are all grouped together in a single item, as "illuminating hydrocarbons." But the percentage which these hydro-

carbons form of the whole mass of the gas is so small that no very serious error can be introduced in computing the total heat-producing power of the gas, if we assume that their specific gravity is equal to that of olefiant gas, and that the ratio of carbon to hydrogen in the whole of them is the same as in olefiant gas, viz., 6 of carbon to 1 of hydrogen, by weight. I shall proceed, therefore, on this assumption.

In converting these volumetric percentages into weight-percentages, I also assume that the specific gravity of olefiant gas is 0.985, and that of marsh gas, 0.556.

Furthermore, in computing the total heat-producing power of this gas, I assume that no heat whatever is absorbed by the mere disruption of the hydrocarbons; or, in other words, that each atom of carbon, and each atom of hydrogen which they contain, produces in their combustion just as much sensible heat as it would do if the carbon and hydrogen were only mechanically mixed instead of being already chemically combined.

On these assumptions then, we have for the 100 cubic feet of illuminating gas, the following results:

Specific gravity,			0.3860
Weight,	Olefiant gas,	0.2856 lbs.	3.1172 lbs.
	Marsh gas,	1.6645 "	
	Hydrogen,	0.2688 "	
	Carb. oxide,	0.6359 "	
	Carb. acid,	0.0234 "	
	Nitrogen,	0.1879 "	
	Oxygen,	0.0511 "	
Combustible ingredients,	Carbon,	1.4931130 "	
	Hydrogen,	0.7257556 "	
	Carb. oxide,	0.0233828 "	
Products of complete combustion in air,	Steam,	6.5318 "	42.8340 "
	Carb. acid,	5.5348 "	
	Nitrogen,	30.7674 "	

Calories produced by complete combustion in air = 33,630.
Maximum flame temperature = 2841.2° C. = 5146° F.

No. 3.—Siemens Generator Gas.—100 Cubic Feet.

The composition of this gas also varies very largely. But a good quality of it would be represented by a mixture of equal volumes of carbonic oxide and nitrogen. I shall assume this composition, from which I deduce the following results for 100 cubic feet.

Specific gravity,			0.96978 lbs.
Weight,	Carb. oxide,	3.9158 lbs.	7.8316 "
	Nitrogen,	3.9158 "	
Products of complete combustion in air,	Carb. acid,	6.1534 "	17.0871 "
	Nitrogen,	10.9337 "	

Calories produced by complete combustion in air = 9,409.667
Maximum flame temperature, = 2354.4° C., or 4270° F.

Comparing now the water-gas with Siemens-generator gas, we see that the former, with a specific gravity but little over half as great, gives a considerably higher maximum flame temperature, and yields for equal volumes nearly twice the total quantity of heat produced by the latter.

But, compared with illuminating gas, the water-gas has about one-third greater specific gravity, and yields about one-half as great a total quantity of heat for equal volumes, while it can produce a maximum flame temperature fully as high as that of the illuminating gas.

It is also worth noticing that the nature and quantity of the products of combustion of water-gas are such that, when discharged at the same temperature, they carry off with them just about the same percentage of the total quantity of heat produced as do the products of the combustion of illuminating gas, while in the case of the Siemens-generator gas, the percentage of heat thus lost is considerably larger.

It is not to be supposed, of course, that the precise results of such computations as these can ever be exactly realized in practice; for the precise data which it is necessary to assume in order to be able to make any computation at all, are in reality never met with in practice. As a matter of fact, Siemens-generator gas never consists exactly of 50 per cent. of carbonic oxide, and 50 per cent. of nitrogen, but is always more or less contaminated with carbonic acid and other impurities, and contains small quantities of various hydrocarbons, etc., the quantity and nature of which vary with different fuels, and with the varying conditions of its production.

And as to illuminating gas, no two samples of it can be found in the country having exactly the same percentage composition; while water-gas itself will never consist entirely of equal volumes of carbonic oxide and free hydrogen, but will always contain small quantities of carbonic acid and some other impurities, together with a greater or less amount of hydrocarbons, according to the nature of the fuel employed in its production; the purest anthracite itself being never entirely free from hydrocarbon compounds.

Nevertheless the data herein assumed are such that, so far as heat-producing power is concerned, they represent good, fair qualities of the three different kinds of gas under consideration closely enough, not only to afford a just basis of comparison between these gases, but also a basis for safe estimate as to what can actually be accomplished with water-gas.

It will be seen from the construction of the apparatus above described, that the percentage of carbonic acid contained in the water-gas, may always be reduced to a very small quantity, inasmuch as it is always easy to have the depth of the coal in the generator sufficiently great so that whatever may be the pressure of the blast employed, the carbonic acid which is formed in the bottom of the generator, where the blast first strikes the coal, must be practically nearly all reduced to carbonic oxide before it issues from the top.

Another circumstance in the construction of this apparatus, which not only greatly facilitates the rapid decomposition of the steam, but also largely increases the length of time during which each successive blast of steam may be continuously sent through the generator, before the latter becomes cooled down sufficiently to require another blast of air, is the very highly superheated condition in which the greatest portion of the steam enters the generator. In fact there is no serious obstacle to having the first portions of every blast of steam enter the generator at a temperature nearly as high as the best fire-brick can stand without danger of glazing.

Another point in connection with this apparatus is the almost absolute impossibility of dangerous explosions. For the pressure being steadily outwards at all times and in every part of the apparatus, if any leaks occur, they can only result in the escape and loss of gas or steam, and no opportunity is ever offered for external air to enter, and form explosive mixtures with the gas inside.

We have already seen that 2000 pounds of anthracite coal of the quality and under the conditions specified above, should be capable, viewed from a theoretical standpoint, of producing 69,336 cubic feet of water-gas, of about equal intrinsic value for heating purposes to one-half the same volume of a fair quality of illuminating gas. It is not pretended, of course, that this result can be fully realized. But leaving a generous margin, it is safe to assert, that in practice on a large scale, the equivalent of 50,000 cubic feet of such gas from each 2000 pounds of anthracite of good ordinary quality, can be realized, and even somewhat exceeded. At this rate, and at $4.00 per ton of 2000 pounds, for anthracite, the cost of the coal required

would be only eight cents per thousand feet of gas. The cost of the labor involved, and interest on capital invested, per thousand cubic feet of gas, will, of course, vary very largely with the scale of magnitude upon which operations are conducted.

The capabilities of development of this apparatus are enormous. The generator, instead of being of small size, and of the exact shape shown in the drawing which accompanies this paper, with doors provided at the bottom for raking out the ashes, from time to time, by hand, may be built, to a certain extent, after the general model of the shafts of iron blast furnaces, with a crucible at the bottom, so that by adding to the fuel a small quantity of the proper fluxes, all the mineral ingredients of the fuel may be melted down and from time to time tapped in the condition of liquid slag, from the bottom of the generator, just as slag and iron are tapped from the crucible of a blast furnace.

There is, of course, no practical difficulty in building regenerative chambers of firebrick of sufficient capacity to meet the requirements of the generator, however large that may be. And there is no good reason why a single apparatus should not be built which would be capable of turning 1000 tons of anthracite into more than 50,000,000 cubic feet of gas per day.

Another item worthy of notice in connection with this apparatus, is the fact that any sort of carbonaceous fuel may be employed therein, which does not offer too much obstruction to the passage through it of a powerful blast of air or steam. If non-coking bituminous coal be used, then the water-gas will simply have its heating powers increased by the amount of the hydrocarbons which it will contain.

Among the anthracite regions of Pennsylvania, an apparatus of this sort could take the coal as it comes from the mines, without breaking, screening, or sorting (except to pick out lumps of rock) and turn it into gas. By taking the coal at the mines, without breaking or screening, its cost per ton would be less than half what the broken and screened coal can be sold for in New York; and with an apparatus of the magnitude just mentioned, the cost of labor would be but a fraction of a cent per thousand feet, so that the total cost of the gas manufactured upon such a scale at the mines, including interest on capital invested, and all other incidental expenses, would probably not exceed five or six cents per thousand cubic feet.

It is also easier and cheaper to transport gas in pipes, than it is to transport coal by rail; and the writer firmly believes that the time is

not far distant when our cities generally will use gas far more than coal or steam for all ordinary heating purposes.

Among the various kinds of apparatus hitherto employed for the manufacture of water-gas, that which seems to possess the greatest efficiency, so far as the knowledge of the present writer extends, is known as the "Strong" apparatus, from the name of its inventor, Mr. M. H. Strong. But that apparatus appears to have several serious defects, among which may be mentioned first, the difficulty of preventing the products of combustion and of considerable quantities of air from mingling with the water-gas, and so contaminating it with somewhat large percentages both of nitrogen and carbonic acid; and second, the difficulty of keeping the fire open so that it will burn freely and not choke up with cinders, ashes, or clinkers, and thus seriously interfere with the regular working of the process. To these may be added, the use of an exhaust, instead of a blast, for producing the draft while air is burning; and, as the writer believes, a considerably higher cost of labor per 1000 cubic feet of gas produced than would be required in a plant of equal capacity of the style above described.

By reference to the cut and description given above, it will readily be seen that the products of the combustion of air can be easily and almost completely excluded from the water-gas, with the loss of but a very small quantity of the latter. Suppose, for example, that the apparatus is at a given time receiving steam through the pipe P, and discharging water-gas through the pipe Q′. When it becomes necessary to shut off the blast of steam, it will be immediately followed through the apparatus in the same direction by a blast of air entering through pipe O. But the valve K′ in the pipe Q′ leading to the gas holder, should not be closed the instant that the valve I is opened to admit the air; but should remain open a few moments longer, until the water-gas occupying the chambers B′ B′, has been swept on to the gas-holder, and the products of the combustion of air begin to appear at the valve K′. The latter should then be at once closed, and L′ opened to send the waste gas to the chimney. When the next change is made, it will be to admit a blast of steam through the pipe P′, and this blast will pass through the apparatus in an opposite direction to that in which the air has just been travelling. At the instant when the valve J′ in pipe P′ is opened to admit the steam, one-half of the whole apparatus will be filled with fresh air, and the other half by the products of the combustion of air. The valve L in the pipe R leading to a chimney, should there-

fore now be first opened and left open until (all the other valves being placed in proper position, of course), the steam has had time enough to drive the whole mass of waste-gases out of the apparatus, and water-gas of good quality begins to appear at the valve L; then, and not till then, should L be closed and K be opened to send the gas to the holder or the purifiers.

With reference to the difficulty of keeping the fire in good condition, which is a serious matter in the Strong apparatus, there is nothing of the kind to be apprehended in my apparatus any more than there is in any good working blast-furnace. The power of the blast can always be adjusted to the work which it has to do, and, as already remarked, all cinders and ashes may be melted down and tapped from the bottom, thus saving much labor of stoking, besides insuring *complete* combustion of the fuel, and avoiding the not unimportant loss of half-burned coal among the ashes, which almost always occurs when the latter are not melted down.

One great advantage claimed for the Strong apparatus, is its alleged capacity to use a very large percentage of its raw fuel in the form of loose fine coal or "slack." But the writer is not aware that these claims have yet been well substantiated. It is very evident that in the experiments reported by Dr. Henry Wurtz,* most of the trouble with the fire must have arisen from the use of so large a proportion of fine coal. And as to avoiding it, as suggested, by having some arrangement which will admit of stirring the fire, though that may be easy enough with an experimental apparatus of small size, I opine it will not be so easy to devise any means of thoroughly and effectively stirring out the ashes or clinkers from fires of such magnitude as will be required in order to manufacture water-gas upon the large scale that will be necessary to make it a financial success.

ON THE OCCURRENCE OF GOLD IN WILLIAMSON COUNTY, TEXAS.

BY PROFESSOR CHARLES A. SCHÆFFER, CORNELL UNIVERSITY, ITHACA, NEW YORK.

In the early part of last year I received a small amount of powdered mineral from Williamson County, Texas, to be examined for silver. The specimen proved to be limestone, slightly colored

* Transactions American Institute of Mining Engineers, vol. viii, pp. 289–304.

by hydrated oxide of iron, and assayed, per ton, \$2521 in gold and \$5 in silver. Supposing, of course, that this was a case of "salt," I applied for more of the material, stipulating that it be sent in lumps, and received several pieces, averaging 3 to 4 cubic inches, which assayed \$46.50 in gold. A third lot, about one peck in amount, consisting entirely of good-sized lumps, assayed \$160.19. Frequently-repeated examinations of the lumps from the second and third lots convinced me finally that in those cases, at least, the material had not been tampered with, and that the gold had been deposited there by natural agencies.

In the month of April I visited the point from which the specimens were said to have been taken, about twenty miles north of Georgetown, and from an old shaft, about 15 feet deep, took a number of samples. At the very top of the shaft there is a hard cap-rock, 4 feet thick, and below, extending through a thickness of about 2½ feet, is a bed of very porous rock, highly colored at many points with hydrated oxide of iron. Below this is a layer of very finely granular limestone of a faint pinkish color, about 6 feet thick, and, still lower, another bed of porous rock 2 to 3 feet thick. The samples previously sent me corresponded exactly in appearance with the rock in the two porous beds. Subsequent examination of fourteen samples taken by myself gave the following results: three contained no gold, four showed a trace, and seven contained amounts varying from \$2 to \$20.67 per ton, the average of the fourteen being \$5.46. These results, though low, nevertheless showed the existence of some gold, and it was therefore deemed advisable to investigate the subject more thoroughly. In the month of June I revisited the place and spent several weeks in prospecting the neighborhood.

Extending through Williamson County from north to south, covering a breadth of four to nine miles, are a number of long, low hills, generally 50 to 100 feet above the surrounding prairies. Near the top of one of these ridges was the shaft previously referred to. The rock was all horizontally stratified, and there was no evidence or probability of any vein. If gold was present in paying quantities, it would undoubtedly be found in the beds of porous rock. To test the permanency of the existence of gold, seven shafts were sunk at various points around the original shaft, and at distances varying from 100 to 300 feet. In all of these the porous strata were encountered, and, so far as the external appearance of the rock was concerned, it was found to be precisely the same as in the first shaft, although the thickness of the beds varied somewhat at different

points. Fifty-two specimens taken from the various points where the porous strata had been exposed, and from the outcroppings of the same, gave the following results: twenty contained no gold, and thirty-two contained amounts varying from $1 up to $231.50, the whole fifty-two averaging $15.20.

Further investigation convinced me that, although these results were apparently highly favorable, nevertheless the average of the whole rock is far below the figures indicated. Selecting from all the points worked thirty-two lots, they were all carefully sampled and the samples assayed. Of these samples thirty-one contained no gold, and one contained $1 per ton. The examination of the dirt taken from the dry beds of the ravines, below the level of the two beds in question, showed sometimes one or two very minute colors, but more generally nothing at all. While, therefore, not desiring to call attention to this locality as a possible source of supply of gold, I nevertheless wish to record the fact that gold does occur at the point in question in moderate amounts.

The most remarkable feature of the occurrence is the fact that the limestone is undoubtedly cretaceous. It is generally stated that gold may occur in rocks of all ages, and Professor Kerr, in a recent paper read before this Institute,* concludes with these words: "From the facts here given, it would seem that gold is so widely diffused that we may expect to find it in any kind of rock." Nevertheless, I believe the occurrence of gold in cretaceous limestone has not as yet been reported in the United States.

As regards the mode of deposition, it is very evident that it got into the rock in the condition of auriferous iron pyrites. The calcium sulphate, resulting from the decomposition of the pyrites and the limestone, has all been washed out, occasioning the porous character of the rock, and the greater part of the brown oxide of iron and the insoluble gold remain entangled in the pores and crevices. At some points the gold has been concentrated by the action of water, while in others it is entirely absent. Unfortunately there is no way to distinguish between the auriferous material and that which is entirely barren, since the amount of the oxide of iron seems to bear no relation to that of the gold present.

There is a tradition, very commonly believed in the neighborhood, that two or three hundred years ago the Mexicans obtained silver there, and, in proof of this, attention is called to a large number of irregular trenches to be found at many points on the hills. These

* Transactions, vol. x., p. 476.

trenches have, with the lapse of time, become partially filled, but in all cases they are easily identified by the large blocks of the hard cap-rock which are strewn around on both sides and in the trench itself. So far as silver is concerned, the popular idea is clearly a mistaken one, but it would seem not improbable that in the days of cheap, peon labor this district may have been worked for the small amount of gold to be found.

SETTLING-TANKS IN SILVER MILLS.

BY ALBERT WILLIAMS, JR., WASHINGTON, D. C.

A LARGE proportion of the work performed in wet-crushing silver mills is devoted to the handling and re-handling of pulp between the battery and the pans. There seems to be no generally applicable substitute for the settling-tanks, and in the present system of constructing mills the tanks involve an amount of labor which may be regarded as disproportionate and unnecessary, in view of the automatic improvements which have been introduced in other directions. This difficulty has been met, however, by Boss's continuous process, in which the pulp flows directly from the mortars to the first of a series of constantly working overflow-pans. This method has been adopted at the Noonday mill, Bodie, California; the Harshaw, Arizona; the Sierra Grande, New Mexico; and the Prietas, Sonora. The continuous process, while giving excellent results with special ores, and under peculiar local conditions (such as a deficiency in water supply), is not, I believe, claimed to be available for all raw-amalgamating mills, notwithstanding its well-merited popularity for certain work. Some trouble has been experienced from the tendency to concentration in the pans, though this can be avoided by skilful manipulation. It has also the disadvantage inherent in combinations of distinct operations; it requires a very nice adjustment of the water supply to obtain full battery efficiency without running the pans too thin, though the latter defect is partially compensated for by the gradual thickening of the pulp as it proceeds through the series of pans. The objection is similar to that which holds in a parallel duplex process, that of combining roasting and smelting in a single furnace, where each operation is injuriously affected by the necessity of fitting it in with another and entirely different one.

In the prevailing type of wet-crushing silver mills, the battery sands after settling are manipulated in one of the three following ways: They are either shovelled into wheelbarrows or cars, and thus conveyed to the pans; or they are dumped in heaps upon the platform immediately back of the pans, from which they are again spaded into the pans; or, if taken from the row of tanks nearest the pans, they are sometimes thrown directly from the tanks into the latter by a single handling. Each of these methods may be applicable in a single mill, according to the arrangement of the tanks relatively to the pans. All involve hard work and the employment of many men. Thus of the force employed in six Comstock mills (the Brunswick, California, Mariposa, Morgan, Scorpion, and Trench) which in 1880 numbered 215 men, no less than 49 were tankmen; and of the crews of two mills in Owyhee County, Idaho (the Ellmore and Jones & Adams), 6 were tankmen in a total of 19. The wages were $4 per shift of 10 and 12 hours. These eight examples show that 24 per cent. of the labor in the mills named consisted in handling the tank pulp. The instances cited include all the data I have at command, and probably show a fair average of the practice in mills of the same type. Remembering the notable saving which has been effected in other details of modern amalgamating mills, it appears that here is a possible opening for improvement.

The object of this paper is to throw out a hint which may invite discussion, and may suggest to the builders of the mills of the future a remedy for the existing clumsy, slow, and expensive mode of handling tank pulp. Instead of the laborious shovelling of the heavy, tenacious pulp to higher levels from the tanks, why not utilize the always obliging force of gravitation? This is already done in passing the ore from the bins successively through grizzlies, rock-breakers, and ore-feeders to the stamps, and in settling the pulp; and after leaving the pans the pulp flows downward to the settlers and thence to the agitators and sluices. In all these stages the movement is steadily downward, and is effected by gravity; it is only when the settling-tanks are reached that an interruption occurs. Suppose now that instead of the ordinary tanks we introduce a series of hopper-shaped boxes provided with gates at the bottom, placing the pans 6 to 8 feet below the usual level, and discharging the settling-boxes into movable troughs leading to the charging-holes of the pans. The position of these self-dumping tanks would be the same as that of the ordinary ones; the grade of sluices from the battery to the tanks would not be changed; and the arrangement of over-

flow gates would be identical. The tank capacity could also be kept the same while diminishing the area; for the capacity of the common tank is determined by the limit of depth from which a man can conveniently shovel—this depth ranging in present mills from 24 to 40 inches, and seldom exceeding 30 inches. The proposed system would allow the compartments to be smaller in area because of their correspondingly greater depth. The gates at the bottom of the tanks could be actuated by levers extending above the pan floor. Perhaps the best arrangement would be to employ hinged bottoms surfaced with burlap, sheet-rubber, or other packing. Any slight leakage would not be objectionable; for the water would be strained as it escaped, and all drippings would collect in a large fixed trough underneath the tanks, from which the water could be conducted to the slime ponds or used in diluting the pan and settler charges. The details of construction can be elaborated by any mill designer.

The plan of using gravity-discharging tanks is, I admit, open to certain objections. It demands steeper grades inside the mill, to allow room for a half floor beneath the tanks, and to give sufficient fall for the sluices from tanks to pans. The work of excavation for foundations would be increased, and the mortar beds would need somewhat heavier backing. On the other hand the area occupied by the building could be slightly reduced. The expense would depend largely upon the natural grade of the site. For a 20-stamp mill the addition to the first cost (given a favorable site) should not exceed $1000—an amount which could be saved in wages of tankmen in a three months' run.

THE DETERMINATION OF MANGANESE IN SPIEGEL.

BY G. C. STONE, NEW JERSEY ZINC AND IRON COMPANY, NEWARK, N. J.

IN common with many members of the Institute, I was much interested in Mr. Kent's paper on "Manganese Determinations in Steel,"* read at the Virginia meeting. Having recently had an opportunity to collect a similar series of results for spiegel, I venture to offer them to the Institute, hoping that they may also prove of interest.

Sample No. 1 was taken at our works, where the spiegel was made,

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* *Transactions*, vol. x., p. 101.

A portion of this sample was sent to one of our customers, whose chemist, A, obtained results different from mine. Portions of this sample were afterwards sent to chemists C, D, and H. Sample No. 2 was prepared by A and myself with great care, and distributed to chemists C, D, E, F, G, H, I, and J. The results obtained are as follows:

Sample No. 1.

Chemist.	No.	Manganese found.	Method used.
A	1	14.66	Acetate, bromine, and phosphate (average).
B	2	15.15	" and phosphate.
B	3	15.30	
B	4	15.11	Potassium chlorate and oxalic acid.
B	5	15.24	
C	6	14.92	Acetate and phosphate.
C	7	15.00	" " "
C	8	15.05	" " "
C	9	15.49	" bromine, and carbonate.
D	10	15.05	Acetate, bromine, and carbonate.
D	11	15.06	
H	12	13.83	Volumetric method.
H	13	13.98	

Sample No. 2.

Chemist.	No.	Manganese found.	Method used.
A	1	12.92	Acetate, bromine, and phosphate.
A	2	12.96	
B	3	13.38	" " " "
B	4	13.44	
B	5	13.53	Acetate and phosphate.
B	6	13.68	
B	7	13.50	Potassium chlorate and phosphate.
B	8	13.58	
C	9	13.52	Potassium chlorate and oxalic acid.
C	10	13.68	
D	11	14.18	Acetate, bromine, and carbonate.
D	12	14.56	" " " "
E	13	13.46	" " " phosphate (average).
F	14	14.41	" " " ammonia.
G	15	14.47	Acetate and bromine, and carbonate.
H	16	12.60	Potassium chlorate and oxalic acid.
H	17	12.72	
H	18	12.86	" " " " "
I	19	12.20	" " " " "
I	20	12.44	
I	21	12.92	Potassium chlorate and oxalic acid.
I	22	13.05	
I	23	12.81	Same method, zinc added.
I	24	12.91	" " lime added.
I	25	10.36	" " alumina added.
J	26	12.95	Potassium chlorate and oxalic acid.

A few words as to the chemists and their methods.

A is a steel-works chemist of large experience. His method is as follows: Dissolve 0.5 gr. in hydrochloric and nitric acids, evaporate to dryness, take up with hydrochloric acid, filter; nearly neutralize by sodium carbonate, add a little acetic acid and sodium acetate, boil, filter, re-dissolve, and re-precipitate, evaporate the filtrates to small bulk and precipitate by bromine, filter, wash, re-dissolve in hydrochloric acid (if any iron is present, nearly neutralize by ammonia, and precipitate with acetate of soda), and precipitate the manganese as phosphate, and wash thoroughly with hot water. A's results, whenever I have had an opportunity for comparison, have been lower than those of most other chemists. I think the reason is probably that he uses an insufficient amount of acetic acid when he precipitates the basic acetates, and by neutralizing the filtrate with ammonia he also loses manganese.

B is myself. Results 2 and 3, in sample 1, and 5 and 6, in sample 2, were obtained as follows: Dissolve 1 gram in nitric and sulphuric acids, evaporate till fumes of sulphuric acid are given off, dilute to 500 c.c., and take 200 c.c. (equal to 0.4 gr.) for each determination, add sodium carbonate until a decided precipitate forms, then 30 c.c. acetic acid (1.047 sp. gr.) and 7 or 8 grams of sodium acetate, dilute to 300 or 400 c.c., and boil gently about twenty minutes, filter boiling, and wash with very hot water, containing 3 or 4 grams of sodium acetate to the liter. Working in this way, I have never found any manganese in the precipitate, and very rarely any iron in the filtrate. Evaporate the filtrate and washings to about 200 c.c. (if any iron separates, filter it out), make acid with hydrochloric acid, and precipitate as phosphate as usual. A determination can be made in seven or eight hours. Results 3 and 4, in sample 2, were made by precipitating basic acetates twice as above, then by bromine, and weighing as phosphate. Results 7 and 8, in No. 2, were by Ford's method.* Results 4 and 5, in No. 1, were by a modification of Williams's volumetric method.†

C is my assistant. His results, 6, 7, and 8, in No. 1, were obtained by the acetate and phosphate method, as I use it. No. 9, in 1, was by *D's* method. Nos. 9 and 10, in 2, were by the modification of Williams's method, which I used.

D is a commercial chemist of considerable experience. Of results 10 and 11, in No. 1, he writes: "Precipitated as basic acetate three times, separated the manganese by bromine, and precipitated finally

* *Transactions*, vol. ix., p. 397.

† *Transactions*, vol. x., p. 100.

by sodium carbonate, washed by decantation, boiling after each addition of water until the washings gave no reaction with coralline. Results 11 and 12, in No. 2, were obtained by precipitating as basic acetate twice, and separating the manganese as before. The analyses were made in a hurry, and the precipitates washed on the filter."

He was not entirely satisfied with the results, but considered 14.18 per cent. the nearest to the truth.

E is a firm of commercial chemists, who have had an exceptionally large experience in spiegel analysis. They precipitate basic acetates, separate by bromine and precipitate as phosphate. I do not know the exact details.

F is a commercial chemist. He uses Troilius's bromine and ammonia method.* The results I think are high.

G is a commercial chemist. He used either Eggertz's or *D's* method, I am not sure which. His results are also apparently high.

H is an assistant in a prominent technical school. Sample 2 was sent to him twice with different marks. His method, as I shall endeavor to show, is defective and invariably gives low results; it is as follows: Solution in hydrochloric acid, boiling with large excess of nitric acid until all the hydrochloric acid is driven off, precipitation while boiling by potassium chlorate, solution of the manganese oxide in oxalic and sulphuric acids, and titration, with potassium permanganate, of the oxalic acid undecomposed. The oxalic acid is standardized by iron wire.

I is an assistant in the same technical school. He used the same method. 19 and 20 were his first determinations. 21 and 22 repeated "with great care." He also tried the method on manganese ores, with results that compared favorably with other methods. Thinking this might be due to the presence of some constituent of the ore, he repeated the determinations, adding zinc, lime, and alumina to the spiegel analysis; the results are given at 23, 24, and 25.

J is a chemist on the State Board of Health. He used Williams's method.

The acetate and phosphate method is, I think, the most reliable; all but one of the chemists on the list who use it agreeing well. It is hardly necessary to precipitate the manganese by bromine before precipitating as phosphate, for while it always gives slightly lower results, the difference is so small that it may safely be disregarded. I give some comparative results:

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* *Transactions*, vol. x., p. 173.

Sample No.	Manganese precipitated by bromine first.	Phosphate direct.	Difference.
39	17.02	17.10	0.08
76	13.38	13.53	0.15
76	13.44	13.65	0.21
312	18.51	18.68	0.17
313	11.79	11.99	0.20
313	11.79	12.02	0.23

If there is ever any necessity for precipitating by bromine, it should be in our spiegel. As our ores contain considerable zinc, we use a very heavy lime charge, and the furnace-working is such as to favor the reduction of the alkaline earths.

The methods in which the manganese is precipitated as hydrate or basic carbonate usually give high results, owing to the obstinate manner in which the precipitate retains alkalies, although by washing by decantation, and boiling the precipitate each time with a large amount of water, it can be removed; but this takes too much time for a busy laboratory. *D* tells me that although you may wash the precipitate on the filter until the washings give no reaction with coralline, yet if you then boil the precipitate up with water, it will give a strong alkaline reaction.*

Needing a rapid and tolerably accurate method for determining manganese in spiegel, I tried Williams's method as promising better than any that I knew of. On making comparison analyses by it and the acetate and phosphate method, I found that it gave me only about ninety per cent. of the manganese, the difference being always proportional to the amount of manganese. The method is based on the supposition that manganese is precipitated by potassium chlorate from a nitric acid solution entirely as MnO_2. It occurred to me that this might not be correct; on trying it I found it was not. To test it I precipitated 0.5 gr. of a spiegel, in which I had previously determined the manganese by Ford's method, by potassium chlorate, and added the precipitate to a fresh solution of iron wire, made as is usual for standardizing permanganate, and, after dissolv-

* A chemist who used *D's* method (not one in the list), told me he always considered it safe to deduct one-half per cent. from his results, and could not be sure of their being nearer than three-quarters of a per cent. to the truth.

ing, determined the excess of unoxidized iron by permanganate which had just been standardized by the same iron wire dissolved in the same manner. The results were as follows:

	No. 1.	No. 2.
Manganese found by Ford's method, ...	0.0675	0.0679
Iron that would be oxidized if the precipitate were MnO_2	0.1374	0.1382
Iron actually oxidized, ...	0.1117	0.1119

This result would give very nearly the formula 10 MnO_2,MnO. I then tried standardizing the oxalic acid solution by a spiegel which had been repeatedly analyzed by different chemists, and obtained excellent results.

The method of analysis finally adopted, is as follows: Dissolve 0.5 gr. of spiegel in 40 c.c. nitric acid (1.42 sp. gr.) by boiling, add gradually an excess of potassium chlorate, cool, filter through asbestos (using a filter pump), and wash three or four times with water. The precipitate will still contain some iron, but it does not interfere. Add the precipitate and asbestos to an excess of standard oxalic acid (8 to 8.5 grams to one liter), add sulphuric acid, and heat till dissolved, titrate the excess of oxalic acid by permanganate (about 3 grams to the liter). The following are the results of *all* the test analyses I have made; most of the determinations are the averages of duplicate or triplicate analyses which agreed well. A large number of the analyses were made by Mr. F. Sands (chemist *C* in the list) who has also done much of the work to test the composition of the precipitate by potassium chlorate.

Sample No.	Acetate and phosphate.	Volumetric.	Difference.
59	9.50	9.50	0.0
83	12.28	12.17	— 0.11
76	13.60	13.60	0.0
69	14.80	14.97	+ 0.17
4	15.23	15.17	— 0.06
112	15.35	15.49	+ 0.14
170	16.94	16.79	— 0.15
39	17.06	17.03	— 0.03
167	17.56	17.62	+ 0.06
164	18.02	18.06	+ 0.04
169	18.26	18.32	+ 0.06
138	18.30	18.19	— 0.11
81	18.35	18.36	+ 0.01
199	18.89	18.79	— 0.10
67	20.71	20.74	+ 0.03
264	67.80	68.00	+ 0.20

My results, 4 and 5 in No. 1, and *C's* results 9 and 10 in No. 2, were by this method.

I think the reason Mr. Williams found his results so satisfactory, was, that he used steel containing about half of one per cent. of manganese for all his analyses. With such a small amount present, of course the loss of one-tenth of it (0.05 per cent.) would make comparatively little difference.

I have some of the sample No. 2 left, and shall be happy to send some of it to any member who would like to try it.

THE BOWER-BARFF PROCESS.

BY A. S. BOWER, C. E., ST. NEOTS, ENGLAND.

Any process which has for its object the preservation of iron and steel from rust, and which will make these metals more applicable than they now are to the requirements of mankind, will be sure to meet with attention from members of this association, and from all those who are either engaged in the extraction of the ore, its reduction to metal, or the subsequent application of the metal itself.

It is, perhaps, not too much to say that when iron and steel are rendered secure against corrosion and decay, they will be used to an indefinitely greater extent than they now are. The whole realm of science has, therefore, been explored in the attempt to discover some method by which the formed article may be preserved, leaving its strength undiminished by the destructive action of rust. Paints, oils, varnishes, glazes, enamels, galvanizing, electro-depositing and what is called "inoxidizing" are among the many systems now in vogue to effect the preservation of iron and steel from the corrosive action of air and water.

The object of this paper is to show what may be done in protecting iron and steel from rust by forming upon their surfaces a film of magnetic oxide by an inexpensive process. It is no new thing to be told that magnetic oxide of iron is unaffected by exposure to the atmosphere or to salt water for any length of time. The black sand of Taranaki, in New Zealand, is a sufficiently good example of this. Dr. Percy has pointed out that the reason why Russian sheet iron is less affected by exposure than ordinary sheet iron is because of a coating of magnetic oxide; but this was not known

until Dr. Percy discovered it. That such a coating is produced is quite certain, but it is only an accident of manufacture. To Professor Barff is due the credit of being the first to deliberately undertake to coat iron and steel with magnetic oxide, produced designedly for the purpose of protecting their surfaces from rust.

Some 16 or 17 years ago my father made a series of experiments in the production of heating gases, one set of them being the decomposition of water by passing superheated steam through masses of red-hot iron. He noticed that the iron became less and less active until it ceased to decompose at all, when, on examining it, he saw that it was coated with a kind of enamel. It at once occurred to him, on seeing this, that the process in question might be used to obtain such a coating, but he found after a few days' exposure of the iron to the atmosphere, that the coating shelled off, and he pursued the matter no further. The iron employed in this case was rusty, but if it had been new my father would in all human probability have been the accidental inventor of the process which Professor Barff discovered ten years afterward. I only mention this to show how advisable it is to investigate the causes of unexpected effects. Professor Barff's process consists in subjecting iron or steel articles to the action of superheated steam, and when they are at a temperature sufficiently high, three equivalents of iron combine with four of oxygen, forming one equivalent of magnetic oxide, and setting eight of hydrogen free, or symbolically (1) $Fe_3 + 4H_2O = Fe_3O_4 + 8H$.

Upon reading a description of the Barff process in the London *Times*, it occurred to my father that what the professor could effect with steam he might also effect with air, and several experiments were made to this end, which were very varied in character, as were also the results obtained. The first was made with cast iron, by placing the articles to be treated in a cast-iron retort, heated externally, and then passing superheated air over them; and it was successful, while nearly all others afterwards were quite the reverse, as sesquioxide was copiously produced as well as the magnetic. Another experiment was made by placing a bar of polished cast iron in the main duct of superheated air to a blast furnace, and this, though covered with a red sesquioxide powder easily brushed off, had a thin, but very firm and tenacious, coating of magnetic oxide in contact with the iron. This bar has been exposed to the weather ever since, or over four years, without the slightest appearance of rust. Ultimately, when thinking over the fact that air is oxygen and nitrogen in mechanical combination only, I came to

the conclusion that, to form the lower or magnetic oxide, the quantity of free oxygen, and so of the air employed, must bear some proportion to the surface of the articles exposed to its action, more especially when a comparatively low heat is employed. This is so, and it has been proved that the quantity of air passed through the retort during most of the unsuccessful experiments was 300 or 400 times more than was actually necessary. The reasons also why the first experiment was successful were that a great number of articles were in the muffle, that a very high heat was employed, and that the retort had been previously used for coal-gas making, and had a deposit of carbon in it, which to a great extent neutralized the effect of the large excess of air.

All the unsuccessfully treated articles were red with sesquioxide outside; but there was, nevertheless, a coating of magnetic oxide in close proximity with the iron, due to the reducing influence of the metal in contact with the sesquioxide at an elevated temperature. The general appearance, however, of iron so treated was disagreeable, to say the least of it. The mode of action I then adopted was to admit a few cubic feet of air into the retort at the commencement of every half-hour, and then to leave the iron and air to their own devices, the retort, of course, being tightly closed. During each half-hour a coating of magnetic oxide was formed, and the operation was repeated as often as was considered necessary. Effective as this was for cast iron, the cost of producing the coating was as great as by the Barff process, for both of them required that the chamber should be heated externally, and this, with large furnaces, is very expensive. Another plan that I adopted was to first find out approximately the extent of the surface of the goods to be treated, by dipping them all into a tank of water of known area, lifting them out, and noticing the amount of water taken out of the tank by the wetted surface, and then to regulate accordingly a slow, continuous air supply by meter, of course keeping the temperature of the muffle as nearly constant as possible. This, too, was successful; but the same objections applied to that mode of procedure as to the other.

There was commenced a series of experiments with carbonic acid chemically produced by the decomposition of chalk, the idea being that three equivalents of iron would unite with four of carbonic acid, forming one equivalent of magnetic oxide and four of carbonic oxide, if the heat were sufficiently high. This reaction is expressed symbolically thus: (2) $3Fe + 4CO_2 = Fe_3O_4 + 4CO$. This is the simplest action that could take place, but it was evident from the

results that something quite different was obtained, inasmuch as the coating was very light in color, pleasing to the eye, but easily removed, and in that sense entirely differing from the articles you see before you. This coating, from effects exactly similar and designedly produced by a studied manipulation in the furnaces in successful operation in England, France and here, proves pretty conclusively that carbonic acid, practically pure, produces upon iron, at an elevated temperature, a film which is, in composition, a mixture of FeO and Fe_3O_4, or, at all events, is nearer the metallic state than is magnetic oxide. But even supposing that the results obtained by the carbonic acid had been successful as then carried out, the objections referred to concerning the air process would still exist, as external heat and a closed iron muffle would always be necessary. I therefore proposed to use a fuel-gas producer, similar in principle to the Siemens generator, but altered practically to suit other requirements, to burn the combustible gases thus produced with a slight excess of air over and above that actually required for perfect combustion, and to heat and oxidize the iron articles, placed in a suitable brick chamber, by these products of combustion. I also arranged a continuous regenerator of fire-clay tubes underneath the furnace, so that the products of combustion leaving the oxidizing chamber passed outside the tubes, imparting a portion of the waste heat to them, which was taken up by the ingoing cold air passing through their interior on its way to the combustion chamber. I had hoped in this way to be able so to regulate the excess of air over that required for complete combustion as to be able to produce magnetic oxide directly, instead of the lower and useless oxide or combination of oxides produced by carbonic acid alone. I obtained some beautiful results, and some again were unaccountably bad, and I soon found that it was as difficult to regulate the precise amount of oxidation as it first was in the Bessemer process, and I was fortunate enough to hit upon an almost parallel remedy—that is to say, I increased thequantity of free oxygen mixed with the products of combustion, and oxidized the iron articles to excess during a fixed period of generally 40 minutes, when magnetic oxide was formed close to the iron and sesquioxide over all. Then for twenty minutes I closed the air inlet entirely, leaving the gas-valve open, and so reduced the outside coating of sesquioxide to magnetic oxide by the reducing action of the combustible gases alone.

The excess of oxygen in the first instance produces Fe_2O_3, or sesquioxide of iron, and the under surface of this, being in contact

with metallic iron, undergoes reduction to magnetic oxide in the following manner: Four equivalents of sesquioxide unite with one of metallic iron, forming three equivalents of magnetic oxide, or, symbolically (3) $4Fe_2O_3 + Fe = 3Fe_3O_4$.

When deoxidizing by combustible gases, consisting mainly of carbonic oxide, three equivalents of sesquioxide unite with one of carbonic oxide and form two equivalents of magnetic oxide and one of carbonic acid, or, symbolically (4) $3Fe_2O_3 + CO = 2Fe_3O_4 + CO_2$. Another method of reduction is by carbon itself, when the formula stands thus: (5) $3Fe_2O_3 + C = 2Fe_3O_4 + CO$.

Formula (4) is also the reaction when rusty iron is reduced by producer gases, which consist largely of carbonic oxide; and by the specimens exhibited it will be seen that articles completely pitted with rust may have their surfaces rendered rustless. In this case the periods of oxidizing and deoxidizing are reversed—that is to say, the latter occupies 40 and the former 20 minutes. No oxidizing is theoretically necessary, but practically a certain amount is requisite to keep up the heat in the chamber, which, of course, could not be done unless combustion took place some time or other. I only mention the reduction by carbon as exemplified by formula (5) because, while experimenting with a furnace, I was asked by the proprietors of a valuable red-oxide deposit, which was found in so finely divided a state as to be capable of being used at once as a paint, whether I could reduce it to a magnetic oxide. I tried to do so by carbonic oxide, but I found that only the surface of it was affected, and that even this, when taken out of the furnace, speedily returned to its original red color, by the combined actions of the hot unconverted material underneath and the air above. It will be found from formula (5) that $2\frac{1}{2}$ pounds of carbon are required to reduce 100 pounds of red oxide. This I mixed intimately, in the shape of powder, with the red oxide, brought the mixture to a red heat, and the result was black magnetic oxide. Not only this, but by adding more carbon I could make the color lighter and lighter until it was almost identical with the coating produced in my previous experiments with carbonic acid, and by reducing the quantity of carbon below $2\frac{1}{2}$ per cent. various shades of purple were obtained, the red appearing more and more prominent as the quantity of carbon was diminished.

It will be as well, before I make any comparison between Professor Barff's process and the processes patented by my father and myself, to state that the whole of the professor's patents, wherever existing, have been purchased by my father, so that in this case, at least, I hope you

will not say that "comparisons are odious." Professor Barff's process is better than ours for wrought iron, and perhaps for polished work of all kinds, as iron commences to decompose steam at a very low temperature; in fact, much below visible redness. Only the other day at the annual meeting of the Association of American Stove Manufacturers, held in New York, I was asked whether stove patterns might not be made of cast iron, polished, and then oxidized? Here is one among many instances where the steam process is almost invaluable. For ordinary cast iron, and especially that quality which contains much carbon, the Barff process is much too slow in its action, and some specimens that I have treated in England have taken as much as 36 hours to coat effectually, which could readily have been finished off in five hours by the Bower process.

The main distinction between the two is that the Bower is much more energetic in its action than the Barff process. The carbon in cast iron impedes oxidation, and so, while cast iron is far more readily treated in the Bower furnace, wrought iron is apt to scale unless it is rusted beforehand. The rust then eats into the metallic surface under the influence of heat, and forms a tenacious combination with it. The objection to the use of a closed muffle externally heated, as in the Barff process, has been almost entirely overcome by simply putting wrought iron into a Bower furnace, previously well heated, then shutting off both the gas and air supplies, and admitting steam into the regenerator tubes. The steam thus passes through the red-hot tubes, then through the combination chamber and its contingent passages, already highly heated, over the articles in the oxidizing chamber, heating and oxidizing them, and thence over the outside of the regenerator tubes, when it parts with a great portion of its heat before passing to the chimney, which is again picked up by the ingoing fresh, cooler steam. In this way the heat in the chamber is highest shortly after the commencement of the operation, and gets gradually lower during the time of exposure, which varies, according to the class of goods, from five to ten hours. At the close of the operation, just before the articles are taken out, everything is moderately cool, and this for steam is the perfection of action, as stated by Professor Barff himself. Steel, I consider, can be equally well treated by both processes, and, indeed, it is natural to expect this, steel being, so far as the quantity of carbon it contains is concerned, between cast and wrought iron. Polished steel, however, is better treated in a low-temperature Barff furnace.

With regard to the quality of fuel burned in the gas producers, a

non-coking gas coal is the best, and Virginia splint has suited very well in this country, and of this about 1 ton every three days is required for a furnace with an oxidizing chamber 13 feet long, 4 feet 3 inches wide, and 4 feet 3 inches high. When a gas coal is employed, it should be fed through the charging hoppers just before each deoxidizing operation, when a smoky flame is of great advantage. I have, however, discovered that anthracite can be used as well as a gas coal, by simply allowing petroleum to drop at the rate of 1 gallon per hour upon the red-hot surface of the coal in one of the gas producers. This method has been exclusively used in the coating of the articles exhibited in this room at the works of Messrs. Poulson & Eger, architectural engineers, at North Eleventh and Third Streets, Brooklyn, E. D., N. Y., to whom I am much indebted, not only for these beautiful castings, but for the constant courtesy and energy they have always exhibited during the erection of their furnaces. At present they have two erected, one a Bower furnace of the size before mentioned, and the other a small Barff furnace for the treatment of very delicate or polished articles.

These magnetic-oxide processes not only protect from rust, but the coating is of such a beautiful color as to render articles ready for the market as soon as they are out of the furnace and cooled. One remarkable feature of them is that there is no more cost (except in the labor of handling them) in treating 2240 articles, each weighing a pound, than there is in coating a cube of metal weighing a ton; and so penetrating is the process that no matter how intricate the pattern may be, every crevice—which it would be almost impossible to get at with a paint-brush—is as effectively coated as the plainest surfaces, as will be observed by examining the specimens exhibited. For art purposes the French gray color, with shades approaching to black, might not always be suitable; but if it should be necessary to use paint on the iron so coated, there is absolute certainty that it will remain on in the same way as it does on wood or stone, and thus iron may be used for constructive work in a thousand directions in which it has not up to the present time been possible on account of its liability to rust, no matter what the coating used to protect it has been.

I can give an instructive instance of this. A company in Paris had expended a very large sum over Dode's inoxidizing process, which process consists in the depositing of a layer of borate of lead on iron or steel and then gilding, platinizing, or bronzing them; and certainly the articles so treated were exceedingly beautiful to look at. But the iron

ultimately rebelled and threw off the coating, so that the shareholders were in a fair way of losing all their capital, when it was suggested to the directors that if their compositions could be deposited direct upon magnetic oxide they would conquer the difficulty. They then applied to my father for specimens of coated iron to experiment upon, and they were so well satisfied with the result that the company purchased all our European patents except those for England, and are carrying on the combined processes on a large scale. They have, besides their furnaces for the Dode process, four large Bower furnaces, two being 36 feet long by about 6 feet 6 inches wide and 6 feet high, and a Bower-Barff furnace, also of large size. Others, moreover, are in course of erection.

Engineers and manufacturers appear far more ready to apply the processes here and on the Continent of Europe than up to the present time they have been in England. Perhaps the reason has been that, so far as Professor Barff's process is concerned, it has only just been shown how large masses can be dealt with—namely, by the use of the Bower furnace. I can show that, for the treatment of underground pipes, wrought-iron sleepers, roofing and the like, the process can be readily applied, and at a cost much less than that of galvanizing, and they will at the same time be infinitely more durable; while for ornamental cast and wrought iron it is scarcely possible to imagine anything more artistic in color than some of the articles after they have been treated. For ordinary hollow-ware for kitchen use, whether of cast or wrought iron, this process is admirably adapted, and though I have been told that the gray or black color will probably be objectionable, yet I imagine, if it can be shown, as can be done, that the magnetic oxide is more durable, more easily cleaned and much cheaper than even the common tinned article, a market will soon be created. Anyhow, the new combined processes are so far developed, and they have been so thoroughly examined by scientific and practical men both here and in Europe (whose testimony to the value and efficacy of them is voluminous), that they have passed from the region of theoretical investigation into that of practical application, and means have been taken for establishing works at different centres in Europe, as will also be done here, for the purpose of coating iron and steel as a trade operation. One firm alone in Scotland, Messrs. Walter Macfarlane & Co., have adopted the process, and their output of ornamental castings per day exceeds 100 tons. It is intended to apply the process to cast-iron gas and water pipes, and as the former have comparatively no pressure to bear, they may be

made much lighter than they now are, if rendered incorrodible; while for water, it will be a great advantage to have both the main and service pipes rendered safe from rust, which not only discolors the water, but forms the nucleus of very troublesome deposits. There is no reason now why wrought-iron or mild-steel pipes should not be used for the same purposes, especially for the interior towns of distant countries, where the first cost of the pipes is but small as compared with the cost of carriage.

My father has himself used gas and water pipes where the cost on arrival at their destination has been five times greater than their first cost in England. If, then, light wrought-iron or steel pipes could be used, not weighing one-third of those made of cast iron, and rendered practically indestructible, what an enormous saving would be effected! Again, in the case of railway sleepers of iron and steel, which are now almost wholly used in Germany, the process is likely to prove of much advantage, so at least I am told by engineers, both in Belgium and in Germany; and if there, why not here? For fountains, railings, and all architectural work, the process is invaluable, and iron may now be used in many instances instead of bronze.

It will naturally be asked, what is the cost of the process? I cannot do better than answer the question by quoting from the report of Professor Flamache, the engineer-in-chief of the State railways in Belgium, who was sent over specially to England to report on the process, by the Public Works Department of that country. His estimate of cost, after a very careful examination and testing of the process was 7½ francs per 1000 kg., or nearly $2 per ton, at, of course, the Belgian rate of expenses. He also gives the cost of coating a certain extent of surface, but this I consider to be completely valueless, as, for example, I have had a furnace full of 56-pound weights, and another time I have had it full of gas-governor tops, the surface in the latter case being perhaps one hundred times more in extent than in the former, while the actual cost of oxidizing would be the same in both cases. He also says that this cost may be reduced, as instead of one workman attending to one furnace he can attend to three or four; also by a better system of taking the articles out than existed in the experimental furnace that he saw.

Sir Joseph Whitworth, feeling much interest in Professor Barff's process, sent to him some steel to be oxidized, so that he might ascertain whether it did or did not lose in strength by the operation, and the result of Sir Joseph's testing was that there had been no alteration whatever. Theoretically, one would rather expect that

iron and steel would be somewhat toughened, as the tendency of the process is to anneal, and would, no doubt, if continued long enough, render some classes of cast iron malleable. A very thin article, if excessively coated, might probably be weakened, due to the fact that the coat of magnetic oxide would form an appreciable percentage of the bulk of the article; but this, of course, is a very extreme case, and one which is not likely ever to occur in practice.

The development of these processes has been a long and tedious business, and one requiring much faith and patience in the midst of most disheartening failures for months together; but to gentlemen connected with the iron and steel industries, and who know well that results are only obtained by patient and well-directed toil, I need not dwell on this, as almost every man who has had to reduce theory to practice has had abundant experience of the same kind.

In conclusion I add a description of the furnace used in the process:

Fig. 1 represents a longitudinal section of the furnace, taken along the line 1—2 in Figs. 2, 3, 4, and 6. Figs. 2 and 5 are transverse vertical sections of the same, taken respectively along the lines 3—4 and 5—6, Fig. 3; and Figs. 3, 4, and 6 are horizontal sections taken respectively along the lines 7—8, 9—10, and 11—12, Figs. 1, 2, and 5. *a a a* are the producers for gasifying the fuel which is supplied through hoppers *b b b*. The carbonic oxide from the combustion of the fuel in the producers *a a a* passes along a conduit, *d* (its flow being controlled by a slide, *c*), to the openings *e*, where this combustible gas meets a current of hot air ascending through a passage, *f*, and is consumed. The products of combustion are thence conducted along a passage, *g*, where they are thoroughly mixed by open brick-work cross walls, *h*, and then return along a passage, *i*, whence they enter, through the oblong holes, *l*, the chamber, *k*, in which the articles to be coated are arranged. After having passed over and among the articles to be coated, the waste escapes downward through ports, *m*, into regenerator chambers, *p*, and thence to the chimney flue, S, heating in its passage the tubes, *t*, composing the regenerator, and which are securely supported by the cross walls W. Cold air enters the apparatus at *v*, through a channel provided with a regulating valve under the control of the furnace tender. This air then passes along the lower rows of regenerator tubes and back through the upper tubes, thus becoming highly heated by the waste gases, and capable of developing greater heat when burned with the combustible gas.

MINING AND STORING ICE.

BY W. P. BLAKE, F.G.S., NEW HAVEN, CONN.

WE are so familiar with water in its liquid and its solid form, that we seldom think of it as a mineral, and still less as a mineral product of any considerable industrial importance, though in the form of ice it is mined and stored up in enormous quantities yearly. The industry is peculiarly American, and in no other country has the business of cutting and storing ice been so well systematized and perfected. The interest has grown steadily from year to year, until it has attained large proportions, the annual production being counted in millions of tons, requiring, in the aggregate, a large investment of capital in all the Northern States. It gives employment, also, to thousands of men and horses, in the depth of winter, when farming work cannot be carried on. Ice is not only a luxury, but a necessity, in our climate, and is indispensable in many manufacturing operations, and finds constantly increasing applications and uses. As the industry has grown, so the necessity for suitable implements and tools has grown with it, and it has become necessary to systematize and cheapen the methods of handling such a large amount of material with rapidity and economy.

As the industry is properly a branch of *mining*, and as our mining literature does not, to my knowledge, contain any description of the methods and appliances used in it, it seems desirable to place a brief description on record in our *Transactions*, and I therefore offer to the Institute the following outline description, based partly upon observations for several years past of the methods and processes employed, and partly upon the information obtained from prominent ice-miners and from the manufacturers of ice-tools. My acknowledgments are particularly due to the firm of W. T. Wood & Co., of Arlington, Massachusetts, for much information in detail, and also to the Knickerbocker Ice Company, of Philadelphia. The wood-cut blocks used in the illustration of this paper, have been kindly lent by both of these firms.

The sequence of operations in getting ice is as follows:

1. Wetting down a light snow.
2. Scraping off an excess of snow, if present.
3. Marking out the field.
4. Ploughing and cross-ploughing.
5. Cutting the channel and detaching large floes.

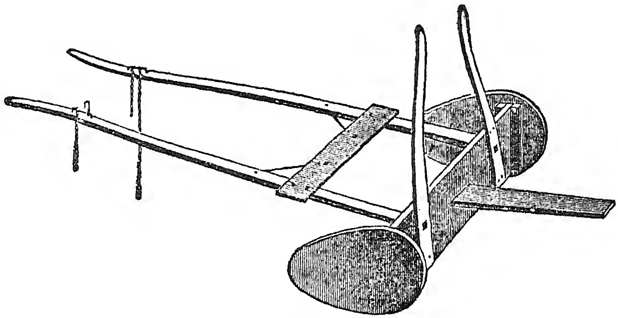
6. Floating the floes to the channel.
7. Splitting off long strips of blocks.
8. Floating them to the foot of the elevator.
9. Dividing into single blocks.
10. Elevating the blocks.
11. Receiving the blocks at different platforms and sliding them into the houses.
12. Storing the blocks in regular tiers in the ice-houses.

PREPARATION OF THE FIELD.

To insure perfectly clean and pure ice, pure, clean water is the first essential. Next, it is important that all dust and dirt shall be kept from the surface of the ice while it is forming and during harvesting. These conditions are best secured by a mantle of snow over the country which prevents dust from being swept upon the ice by the winds from adjoining roads and fields. But snow upon the ice is undesirable, although when the winter is open and ice does not form of sufficient thickness for economical harvesting a covering of snow may be utilized by flooding or "wetting down," as it is termed, so as to gain a greater thickness of ice. This flooding is accomplished by a number of men with ice-chisels, who traverse the ice-field in parallel lines about six feet apart, and punch holes through the ice at intervals of six feet as they advance. The weight of the men causes the ice to bend downwards, and the water rising through the holes penetrates and is gradually absorbed by the snow. The action is slow, and the snow is reduced in bulk to one-third or even one-quarter of its thickness when dry. The same operation is sometimes executed, not to gain an increased thickness for harvesting, but because the ice may be too thin to permit horses to be used upon it; and often because an inch or two of snow ice is regarded as an advantage in protecting the clear ice below it from thaws before a good thickness for cutting is reached, and also because it makes the cakes of ice tougher and less liable to breakage in handling. But a full thickness of clear ice—from twelve to fifteen inches—and without a heavy covering of snow is the most desirable form in which the ice can be had. This, however, is rare. Probably such a favorable state of the ice is not realized oftener than once in ten or twelve years.

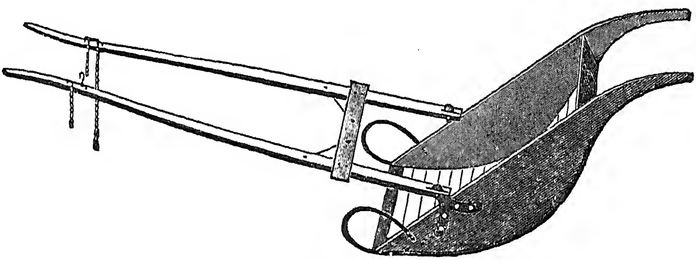
After the first light snow is wetted down, and before the ice has fully grown to the desired thickness, other snows may accumulate, and must be removed before the operation of marking out and cutting commences.

Light dry snow is scraped off by means of scrapers or scoops, which vary in construction in different places, but are arranged to be drawn by horses. A common form of clearing-off scraper six feet long, is shown by the annexed figure.



Clearing-off scraper.

Heavy snow requires a scraper formed like a scoop, so that the snow may be moved in it to a considerable distance. The scoop-scraper is generally three feet wide and is fitted with an iron or steel-edge plate. It is shaped as shown in the figure, and besides the ordinary use for cleaning off heavy snow it is used to take away the



Scoop-scraper.

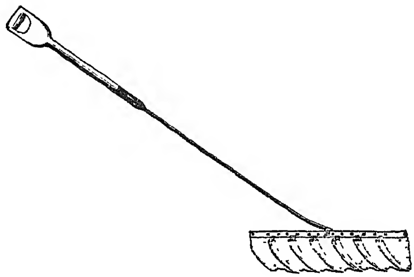
wind-rows of snow left by the clearing-off scraper. On small ponds it is necessary to dump the snow on the shores, but on large lakes and rivers, where there is abundance of room, the snow is dumped at one side out of the way.

MARKING OUT THE ICE.

The ice being cleared of snow, the next operation is marking out of the field, preparatory to cutting.

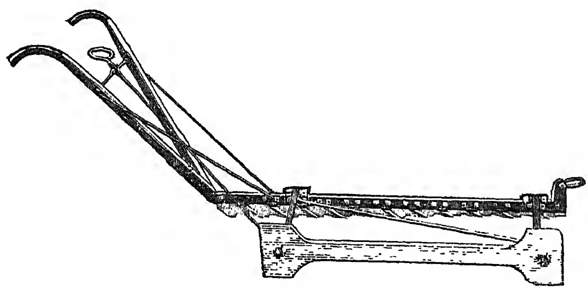
There are various ways of striking the first line. Some stretch

a line between two pins set, say 200 feet apart, and then follow this line by a "marker" carefully guided by the hand so as to preserve a straight line. Others use a straight edge of plank fitted with sights, and this is the best method. Two stakes are first set up in the desired direction of the first cutting and at the side of the field. These may be set 500 or 600 feet asunder. The plank is then brought into line between the stakes, by means of the sights set in each end. A hand-plough is then run close to the edge of the



Hand-plough.

plank from end to end, following it as a ruler is followed by a pen or a knife. When a straight groove is cut about half an inch deep, the plank is moved one length ahead and is again brought into line by the sight, and so on the operation is repeated until the full length of the line is marked out by a straight groove in the ice. This is the initial or base-line of the cutting, and it is followed by a tool called a "marker" provided with a swinging guide. The teeth of



Marker, with swing guide.

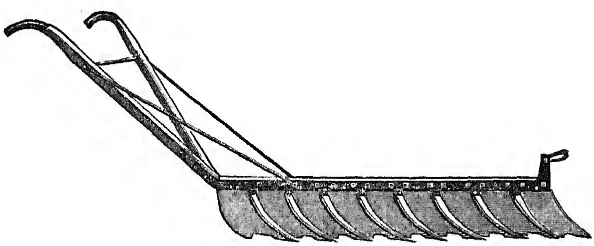
the marker are placed in the shallow groove and run across the field, deepening the groove to three inches and leaving it $\frac{7}{16}$ths wide. During the progress of this first cut, the guide is either taken off or is allowed to slide alongside on the smooth ice with the handle thrown out of the retaining-notch, the tool being guided by the eye and hand of the operator, aided by the groove. In this manner one

straight groove three inches deep is made across the field at one side. The guide is then brought into use and is swung over the back of the marker and takes its place in the groove. The distance between the guide and the teeth of the marker is generally 22 inches. The tool is then drawn back across the field and a second groove is cut parallel to the first and 22 inches distant. This operation is repeated until the desired width of field has been traversed and marked by the parallel grooves. Although 22 inches square is a common size of ice-cakes, shippers of ice usually cut their ice 44 inches square and house it in this form, cutting it up afterwards into 22-inch cakes in the summer. When this large size is required, the guide is set 44 inches from the marker, and the field is then marked off in half the time required for 22-inch marking.*

The cross-grooves are next cut in a similar manner. Care must be taken to secure a right-angled intersection of the front cross-groove with the others. This result is usually secured by a large wooden square, placed on the ice with one edge laid along the first groove, while sighting along the other edge to get the position of the stake. A better method would be to use a line and strike two curves as in draughting, so as to strike a perpendicular. With two marking tools the two systems of lines can be run simultaneously, and much time may be gained.

PLOUGHING THE GROOVES.

The next tool brought into use is the ice-plough, by which the



8-inch plough—8 teeth.

grooves made by the markers are cut to the required depth, generally to about two-thirds the total thickness of the ice.

The ice-plough is a very important instrument, and has finally reached a highly perfected form, as the result of many years of experience and effort. Its invention and first manufacture dates back as

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* For further observations on the size of the blocks, see *infra* p. 349.

early as about the year 1839, and it has now generally superseded the use of the saw and the axe for cutting ice.

The form and construction are indicated by the figure. It consists of a succession of curved, blade-like teeth, attached to a long beam with interspaces in the teeth for the escape of the ice chips. These teeth are now so formed as to clear themselves and carry the chips neatly out of the groove with little resistance. In noting the progressive improvement of ice-ploughs, I cannot do better than to quote from the description given by Messrs. W. T. Wood & Co., of Arlington, Massachusetts, where the manufacture of ice-tools was established in 1834. "The plough was first made with wooden beams and with iron teeth. steeled and widened or upset at the point only. Next, iron beams of equal width were substituted for the wooden ones. Then followed various alterations, such as flanging the teeth the entire face so as to carry out the chips; making one beam wider than the other, to give room for the chips on one side; cutting out chip-spaces in the narrow beam, thus allowing the chips to shoot out freely from between its teeth and permitting the plough to run to its *full depth;* cutting out the bottom of the teeth, leaving only the heel and point to be fitted; making the best ploughs of *steel* teeth instead of iron and steel; improving the curve of the teeth; increasing the degree of finish, etc., etc." "Amongst some of the further experiments referred to may be mentioned, double-markers, combination plane and marker, teeth shaped like a lumber-marker, slanted back so as to *draw* through the ice, ploughs with sixteen teeth, gouge-pointed teeth, teeth with grooved spaces, called the lateral-cut, and many others."

A well-equipped ice company is provided with a full set of ploughs made to cut to differents depths, so that one size may be used to follow another.. There should be one 6-inch nine-toothed plough, one 8-inch, eight-toothed, one 10-inch and one 12-inch plough, and all of them used simultaneously, each following the other in the order of the depth of tooth. Each plough cuts about two inches at a run, and by having a full set and using them in sequence as described, a field of ice can be grooved much faster than where one plough has to do all the work.

CUTTING A CHANNEL.

While the ploughing is in progress, or before, a channel is cut through the ice between the cutting ground and the incline or elevator, by which the blocks of ice are raised and delivered to the ice-houses. This channel is cut by ploughs which are allowed to cut

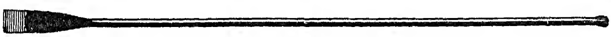
nearly through the ice. The grooves so made are followed by sa\ which complete the separation. A narrow strip of ice is thus (free from the surrounding surface, and is then pressed down a under the main ice sheet, and a wider strip can then be cut lo(and sunk, or harvested if suitable.

The channel being opened, and the elevators in readiness, the n(operation is to detach large floes of the grooved ice and float th(towards the elevator. This is accomplished by first sawing in t grooves across the ends of the block or "float" desired. Sucl float, if there is sufficient space, may be 100 feet or more in leng large enough to sustain the weight of several men. It is common cut them seven or eight cakes (of 44 inches square) wide, and ten twelve cakes long. The sawing is done at right angles with t open water-space into which the floes are to be forced; there is th but one long side to be detached, and this is split off the main bo by "breaking-bars," broad, wedge-shaped chisels. It is sufficie

Breaking-bar.

for workmen to follow along one of the grooves and to plunge t broad wedge into it at intervals with considerable force; a crack is th started and can be followed up and extended the full length of t floe. When the separation is complete, the mass slowly floats aw into the open space, and is directed through it to the channel by t workmen with long ice-hooks, or by lines extending to the firm around the open space.

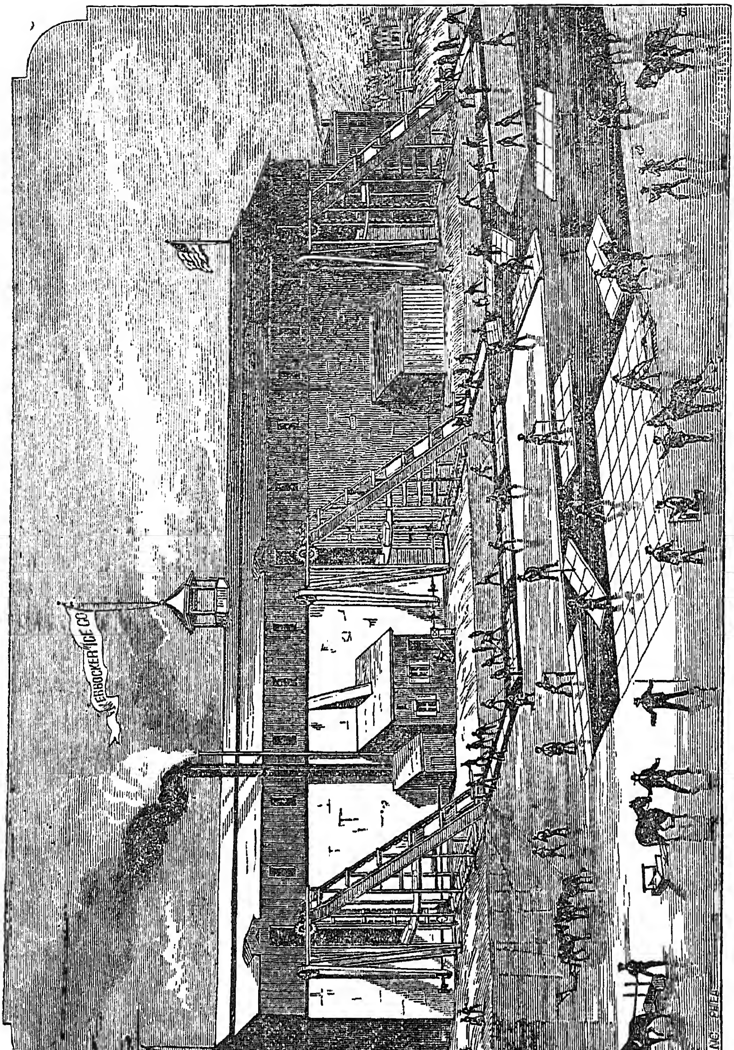
The floe is then to be divided up into long strips, by means fork-bars; three men striking together in the same seam at interv until the strips are detached. These may be one or two cakes wi according to the elevator, either single or double. These long str are then floated into a narrow channel leading up to the foot of t elevator, and as they pass along, one or two men stationed at the s of the canal on a plank platform, separate the cakes by striki lightly in the transverse grooves with a "canal-chisel," a tool six f long, with a hollow handle to secure lightness.



Canal-chisel.

The whole of this series of operations, together with the arran ment of the elevators and ice-houses, are well shown by the wood-

for which I am indebted to the courtesy of the Knickerbocker Ice Company of Philadelphia.



Ice-cutting scene, with the endless chain in operation.

ELEVATION OF THE ICE.

The ice is lifted from the water by steam-power high enough to be distributed on ways, by sliding, into any part of the ice-house. The apparatus generally used is an endless chain working on an in-

clined plane, the lower end of which dips below the surface of the water. The chain is double, consisting of two single chains side by side and about five feet apart, for 44-inch cakes, with wooden cross-bars connecting the chains at intervals of 6 feet. Large, open, rectangular spaces or links are thus formed, large enough to admit a cake of ice between the bars, which extend across between the two strings of the chain.

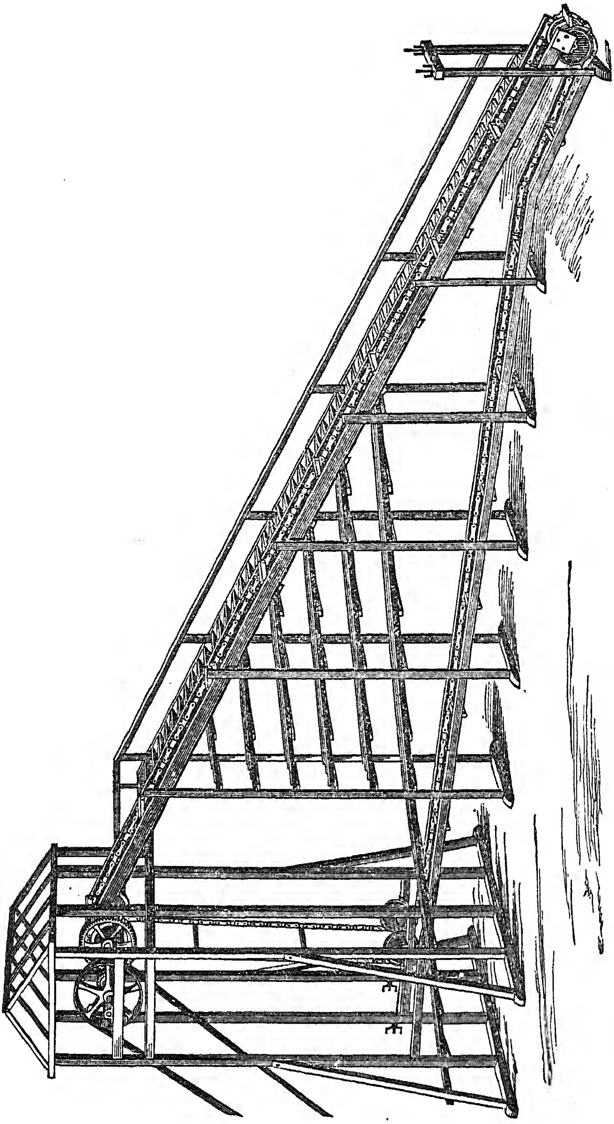
The ice-cakes, as they are separated from the long strips in the channel, are pushed forward to the foot of the inclined plane over which this chain is moving, and being caught by the cross bars are carried along up the incline, each link or space on the chain taking one cake and depositing it at the first opening made in the floor of the incline, the cakes dropping through upon the platform of a second incline or guide-way with a gentle descent in the opposite direction, leading into the building. A series of such platforms and guide-ways is requisite. They are built one above another, about six feet apart, until the upper one will deliver the ice to the highest point, or layer, to be filled in the building. The lowest comes first into use, and the others in succession, as the building fills up with ice. Usually four runs are sufficient. When there are several ice-houses placed side by side, the guide-ways or runs are made to pass the doors of all the houses, and the ice can be turned at pleasure into any of the houses.

The construction of an overshot inclined plane elevator and endless chain is shown on the accompanying cut, showing also the driving pulley and gearing. It is arranged with a stairway alongside the chain for the convenience of the workmen. Six platform-runs are shown, the lowest one only being prolonged to the ice-house.

The elevator-chain is moved by steam power. The speed varies at different places and under different conditions. The highest rate of movement brought to my knowledge was obtained on one chain (with five-feet spaces for 44-inch cakes and the cross-bars six feet apart) where 50 blocks were raised to the minute, each block being 44 inches square and 15 inches thick and weighing fully 1000 pounds. This lifting was thus at the rate of 25 tons a minute or 1500 tons per hour.

To receive and stow away such an enormous supply, it is necessary to have at least twelve doors or houses to deliver into. Two men are stationed at each door, and as the cakes of ice sliding down the guide-way pass the doorway, the men select the cake due their door and pull it in by means of ice-hooks upon a branch guide-way

or run leading into the building. When once landed upon the floor of ice already laid down in the house, the men stationed there receive the blocks and slide them into their proper places, side by side and



Overshot inclined-plane elevator and endless chain.

tier after tier. To facilitate storage in large houses, movable slides and switches are used to guide the cakes of ice to different parts of the building, thus saving time and labor.

Another form of apparatus for lifting the ice has been invented, and is recommended by the Knickerbocker Ice Company of Philadelphia. It consists of a revolving vertical spiral platform, a screw elevator, which takes up cakes of ice from the water and delivers them at any required height to the runs leading into the ice-house.

The grade of ice-runs is an important matter. If too steep the ice will move with great velocity, and be more or less broken up; if too slight, there will be a loss of time and labor. With ice ten inches thick and upwards, the grade may be $\frac{5}{8}$ of an inch to the foot, and if less than ten inches thick, the grade may be $\frac{3}{4}$ of an inch to the foot. In warm weather the ice does not run as freely as when it is cold, and the ice is dry.

ICE-HOUSES AND STORING.

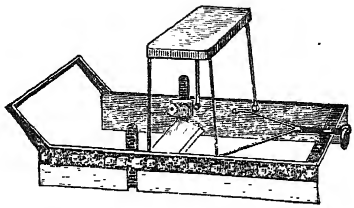
The most improved ice-houses are now built 100 or 150 feet long and 40 feet wide. This width is found in practice to be the most convenient, so much so that even if a large house is built under one roof, it is divided up inside into apartments from 36 to 40 feet wide; for when the ice slides down the centre-line of the house on the run, it is conveniently near either side, so that on reaching the end of the run (made in ten-foot sections) it is easily directed or "shunted" to the place it is needed to fill.

In storing, the cakes are placed so as to leave a 3-inch space all around them to prevent undue wasting when they are broken out in the summer season for delivery. It therefore becomes necessary to break joints every few tiers as they are laid up, by lapping the cakes over in such a way that the joints are covered. In Maine it has been the custom to cut the cakes of ice 44 x 22, thus giving a rectangular block, with which it is easy to break joints in packing. It is now, however, becoming common on the Kennebec to cut the blocks 22 x 32, known as the "New York size," 22 x 22 being rather too small, and 22 x 44 too large. Some cut the blocks 22 x 30 and also 22 x 28, but all for shipping.

PLANING.

The ice-field, when covered with porous snow-ice to any great depth, must be *planed* off, the snow-ice being too hard to yield to the scrapers. The operation is performed in the following manner: After the marker-grooves have been made and at a distance not exceeding 22 inches, a machine called the snow-ice plane, constructed as shown in the figure, is used. The sides of this plane are 22 inches

apart and are fitted to run in the grooves made by the marker. If drawn by two horses as much as three inches can be taken off at once. If more snow-ice than this must be removed, the plane must be run over the surface a second time. The shavings or chips from



Snow-ice plane.

the first planing must be removed by scrapers. This is often a disagreeable operation, as the chips are flat and sharp and often cut the horses' legs, and are difficult to pile up, especially when the weather is cold. The operation of planing is always avoided if possible.

COST OF CUTTING AND STORING ICE.

The cost of cutting ice and packing it away in the ice-house varies greatly, according to the varying conditions and the perfection of the arrangements and the skilful use of all the appliances. With an unlimited supply of good ice, say 10 to 12 inches thick, the cost may be as low as 12 cents per ton. At an ice-house where some 10,000 tons were harvested during the past winter, the cost was estimated at 15 cents per ton. The average cost is nearer 25 cents.

When the crop is abundant it is not unusual for the owners of the plant for filling large ice-houses, after the houses are filled, to continue cutting for the benefit of persons who wish to fill private ice-houses. This is practiced near some of the populous cities and villages within carting distance from the lake or river. Ice, the past winter, was sold in this manner at Lake Whitney, two miles from New Haven, at 40 cents per ton on the platform by the roadside ready to load into wagons. The cost of carting to the city was from 50 cents to 60 cents per ton, being more than the cost of cutting and raising the ice to the platform.

WASTAGE AND LOSS.

But the first cost of the ice, as stored away in the ice-houses, is not a just basis of an estimate of its final cost to the ice-dealer when it leaves his hands and passes into those of the consumer.

The loss in weight of ice by melting, evaporation, and breakage is very great, and is an important item in the business, for although ice may be gathered and housed at an apparent trifling cost, only a fractional part of the quantity harvested is utilized. One dealer, who puts up some 10,000 tons yearly, estimates the wastage at 25 per cent. by melting in the houses during the season, 25 per cent. in taking out and carting, and of the remaining one-half there is often a loss of 33 per cent. in retail vending, or a total wastage of four-sixths of the entire amount stored. This is probably a large estimate. Others place the loss by melting from the close of winter to the end of the season at 25 per cent., and an additional loss of 25 per cent. to 30 per cent. in carting and delivering to consumers.

CHIEF CENTRES OF ICE INDUSTRY.

It is estimated that the consumption of ice in the city of New York is upwards of 700,000 tons annually, with an annual increase of 15 per cent. There are fifteen or more ice companies, besides small dealers who buy of the large companies. The manufacture of artificial ice does not appear to affect the demand for the naturally formed article.

The Upper Hudson is a great source of ice for the New York market. Those who travel between New York and Albany, either by boat or by rail, cannot fail to notice the many large ice-houses which crowd the banks in some places from Troy and Albany as far down as Rhinebeck, Rondout, and Kingston. The river not only yields the product, but in summer gives it cheap transportation.

The conditions for the ice industry are thus exceptionably favorable. Full statistics for the present year* show that there are nearly two hundred ice-houses along the river, with a storage capacity of from 500 tons to 60,000 tons each. The total amount harvested this year is not less than 3,000,000 tons,—one of the largest harvests of ice ever gathered along the river. The ice-crop for the past six winters has been as follows:

Year.	Harvested. Tons.
1878,	2,408,500
1879,	2,061,500
1880,	150,000
1881,	2,500,000
1882,	2,000,000
1883,	3,000,000

* Published by the Albany Evening Journal, January, 1883.

A considerable part of this ice was from eight to ten inches thick, and some of it was fourteen inches thick. The harvest commenced as early as December 8th, but a thaw interrupted the work, and it was not actively resumed until January 8th, 1883, and the principal houses were filled within the next thirty days.

A favorable winter for ice on the Hudson and an abundant harvest, makes it less desirable to lay in a heavy store at the ice-houses in Maine. On the other hand, an unfavorable season in New York is advantageous to the more northern dealers.

The Kennebec River in Maine is also a favorite region for harvesting ice. It has the advantage of rigorous winters and the crops rarely fail. The deep inlets and ponds give easy access to vessels and cheap transportation to domestic and foreign markets. Several of the principal ice companies of New York, Philadelphia, Baltimore, and Washington have large ice-houses along the stream, and secure a supply there when the winter fails to give the required crop nearer to their consumers. The greater part of the Kennebec, from Bath and Woolwich up to the dam at Augusta, is marked off to different ice dealers and is dotted with ice-houses. A map of this region, with a full list of the companies and firms engaged in the ice business, and statistics of the production of ice in Maine, is published annually by Mr. A. G. Chase, of Gardiner, Maine. Considerable quantities of ice are gathered along the Penobscot, the Cathance River, and along the coast, as will be seen by the annexed summary for the years 1882 and 1883.*

Locality.	Year 1882.	Year 1883.
Kennebec,	1,029,200	931,900
Penobscot,	146,000	112,000
Cathance,	39,000	22,700
Coast,	349,000	297,900
Total, tons,	1,563,200	1,364,500

The falling off is attributable to the abundant harvest on the Hudson and at other points.

Besides these main centres of the ice industry, ice-houses are scattered over the interior of the New England and Northern States, and full statistics of the annual ice production are not readily attainable. At New Haven, Conn., for example, the main supply is from Whitney Lake, where 10,500 tons were harvested this winter, and from Lake Saltonstall.

* Figures for 1882 from Chase's map, and for 1883 from the Ice Trade Journal.

Upon the Pacific Coast ice for the San Francisco market is harvested in Alaska, partly at Sitka and partly at Kodiak, the winter at Sitka often not being sufficiently severe to make thick ice.

The ice interest of the country is sufficient to sustain a monthly paper devoted to the ice trade.* It is published by the Knickerbocker Ice Company of Philadelphia. This company is organized on a basis of $1,500,000 capital. It has 250 delivery wagons and employs 800 persons. The total annual ice-crop of the United States is estimated at 20,000,000 tons, and the consumption 12,000,000 tons, the difference being waste.

NOTES FROM THE LITERATURE ON THE GEOLOGY OF EGYPT, AND EXAMINATION OF THE SYENITIC GRANITE OF THE OBELISK WHICH LIEUT. COM'D'R GORRINGE, U. S. N., BROUGHT TO NEW YORK.

BY DR. PERSIFOR FRAZER, PHILADELPHIA.

THE subject of Egypt, to use the words of perhaps the second of modern writers on the subject [Deodat. de Dolomieu, in *Observations sur la Physique, etc.*, January, 1793, vol. xlii., pp. 41+, 108+; Abbé Rozier, J. A. Mongez, and J. C. Delametherie, Paris], is one which strongly excites our interest, and everything relating to it demands our respect. "Thus," he continues, "the Greeks appeared to the Romans," . . . "thus Egypt appeared to the Greeks, and thus all three appear to us." This writer, in the three parts of the mémoire given above, speaks of Norden as the modern pioneer of Egypt, and does not seem to have made original observations himself; nevertheless he seems to have rendered the same service to his authority that Playfair not very long afterward rendered Hutton.† The limitations of a paper will permit little else than citations, but these are so numerous that, unless much compressed, they would supply a chapter of moderate size. A great deal of the very interesting mémoire of Dolomieu is taken up with Quixotic tilts

* Ice Trade Journal, Philadelphia.

† See note of Rozière on first page of Mémoire sur la vallée de Quoçeyr. He never went to Egypt till Napoleon's army went there, and then, disgusted at not being able to go where he pleased in the Thebais, he returned to France, just as the conquest of the country would have permitted him to indulge his fancy for wandering.

against many views then just passing through their ordeal, which have since become firmly established.*

It is impossible to resume all the subjects of interest touched upon by Dolomieu in the few lines that are permissible here; touched upon too with the felicity with which Schiller treated the geography and scenery of his drama of William Tell, and under the same conditions. Those who are interested in the questions which follow, are strongly advised to peruse this many-headed mémoire.†

According to Norden it is 160 leagues from Cairo to the commencement of the granites [on the map of Egypt, in the *Description de l'Egypte, Antiquité, Mem.*, vol. ii., this distance (about 772 kilometers) would bring the point indicated to the principal quarries, 20 kilometers below Syene], in the mountains known as "Tschabel Esselsele," or "Mountains of the Chain, and so called because the Nile runs in a gorge so narrow that there is no more than room for the passage of its waters; and its course has been barred by an iron chain." If the drawings of this traveller be accurate, the *granite* (?) is in very thick, horizontal and parallel beds. It is in these mountains, up to some distance above Essouan (the old Syene), that the old quarries of red granite are found, "whence they have cut such a quantity of obelisks and columns, that all Egypt seems to be

* This was in 1793, in Paris; and one of the editors (M. Delametherie), in the "discours préliminaire," while recounting the scientific events of the year, remarks apropos of Lavoisier's construction of machines for weighing accurately a certain volume of water, "I have begged for a long time that we should adopt this system" (of connecting weights and measures), "and I renew the request that I have also heretofore made, that the commencement of the year be fixed at the vernal equinox." At a time when the strongest social and political tyrannies were crumbling to dust before the exaltation of a self-asserting people, it did not seem too much to put such a modest demand into so few words.

† Its divisions are as follows: "1st. Is the entire soil of Lower Egypt really a product of the deposits of the Nile? 2d. Is it really true that the soil of Egypt is raised so much as to tend to withdraw it from the inundations of the Nile? Is it necessary that the floods of the Nile should be now more considerable in order to produce complete inundations, and to extend fertility over the whole Delta? If there is a mistake in the estimation of the flood of the Nile, whence does it come? 3d. Was the increase of the Delta caused by the deposits of the Nile much more rapid once than it is now? Do these deposits augment the extent of Lower Egypt? Can one withdraw the story of Homer from the region of fable, and would it be possible to believe that the great distance at which he places the island of Pharos from the coast of Egypt is not a poetic fiction?" It will be observed that all of these questions (most of which he answers in the negative) are merely indirectly connected with the subject of this chapter, but the mémoire is of sufficient interest to justify reproducing its headings.

yet covered with them in spite of the immense number which have been transported to Rome." (i. l., p. 42.)

By reference to this map before mentioned [*Carte Ancienne et Comparée de l'Egypte*, par M. le Col. Jacotin et par M. Jomard, etc.] the chain referred to does not indicate its direction by any modifications of the surface topography which are represented cartographically; nor are there any indications in the new atlas of Linant Bey [*Mem. sur les principaux travaux publiques*, etc., Paris, 1872–73]. In the grand atlas [Feuille, No. 3, *Description de l'Egypte, carte Topographique*, elephantine size] there is a simple legend, "Mountain of the Chain," engraved parallel with the course of the Nile, but no indication of the trend of the mountain. Over 100 kilometers northwest of this is a mountain chain in the desert of Libya, of which part is given as granite. The map in another volume of this monumental work, *Ægyptus Antiqua*, by D'Anville, is no more satisfactory, but the views of the cataract of Syene, in the same atlas, are splendid, and need no further explanation to inform the geologist just the kind of occurrence we have to deal with. In the lowest figure (1 of Planche, 30 A, vol. i.) the production of the Cataracts by the remains of the hard rock in the bed of the river where it crosses, will remind one of many similar phenomena, which he has observed, where dikes of trap cross streams of larger size. Here the Libyan chain is figured as running east and west, close to the northern bank of the Nile, while the Arabian chain passes up from the southeast to the northwest, and intersects the former within the limits of the town. The town is, therefore, more or less dotted with hills and knobs of the red granite, although its situation was evidently chosen to withdraw it from the rougher rocks "covered with gravel and sand," as they are described by the topographers under Napoleon. In describing Lower Egypt from Norden's notes, Dolomieu resumes it by saying, that "everything which is not calcareous rock is transported matter." In order of time the superb work of the scientific men who accompanied Napoleon the Great in his campaigns into Egypt, is next to the work Dolomieu just cited.

Rozière, the celebrated mining engineer, who was charged with most of the geological and mineralogical work, gives in vol. i. "*Antiquités: Description*," a "Description de Gebel Selseleh (Mountain of the Chain) et des Carrières qui ont fourni les matériaux des principaux édifices de la Thebaidé." He mentions the fact that the greater part of the monuments which exist to-day came

from near Syene, whereas a large number which have disappeared were built of calcareous materials, that belonged to a region considered by him as intermediate between the calcareous and the granite which forms the base of his mémoire. This region stretched from Syene, that is, from the first cataract, to within a day's march of Latopolis.

A third class of monuments to which he devotes a mémoire was hewn from those rocks which extend from Thebes northward—the calcareous rocks of which the pyramids were built.

Rozière declares himself a partisan of the theory, that the words "Mountains of the Chain" have reference, by a very natural Oriental imagery, to the obstruction to invasion that such a barrier would present. In speaking of the materials which the Egyptians used for their monuments, he compares the sandstone to that of Fontainebleau, but the shades of color are much more varied in the Egyptian rocks. Many varieties contain small specks of black, yellow, and silver mica, *which are not found at all in the countries of tertiary origin which are separated by a broad expanse from the primitive rocks.* Outside of this, these sandstones have numerous black, brown, or yellow spots, due to argillaceous earth and oxide of iron. He combats the assertion of earlier writers, that the surfaces are generally polished, and thinks that they are generally rough to the touch and of little durability. At the same time the stone, instead of being difficult to cut on account of its siliceous nature, is, on the contrary, extremely sectile, as he convinced himself by trial. He makes a curious calculation, that if the same amount of money and labor employed in these monuments had been employed on similar works in marble, not a fifth part of them would have been executed. In his description of the manner of cutting out thin blocks, he explains the grooves, shaped like an inverted V, with which the entire vertical surface of the rock, whence a stone has been taken, is covered, by supposing that the chisel employed was first driven into the rock to its head, at a slight angle for convenience, and that then it was turned in the opposite direction, as the easiest means of making the largest separation with a given tool from one point. The horizontal drill-holes which bounded the stone, on the contrary, are difficult to explain, and while perfectly straight, advanced at each blow three or four inches. "What immense force," he exclaims, "must have been employed to accomplish such a result!" In a note here, Rozière makes an observation, which is extremely interesting. "I might ask," he says, "of what material the tool was made, for it is not certain (in spite of what has been said on the subject) that the Egyp-

tians knew iron from all antiquity (*de toute antiquité*). I will submit elsewhere reasons for a contrary opinion." He believes that, while the Egyptians always tried to have an end of the quarry open in order to have their surfaces free, they invariably employed wedges, and no other tools, to break off the rock horizontally from its base. Neither he nor others have remarked the traces of tools on this surface.

In his picture of a quarry (A, vol. iv., Pl. 65) near Beny Hassan, the faces left exposed cause the whole structure to resemble a house. The pictures and chart of the chain in the neighborhood of Syene are very remarkable for the basaltic columnar appearance they have (A, vol. i., Pl. 30). This same appearance is repeated, though not in so striking a manner, in the pictures of the environs of Assouan or Syene (E. M., vol. i., Pl. 1). Before leaving the volume it is well to call attention to the different appearance of the topography in the neighborhood of Cairo (E. M., vol. i., Pl. 15), where the abrupt hills in the vicinity of the town are represented by hachures, and utterly unlike the configuration assumed by the crystalline rocks, correspond well with the description of the Gebel el Moquattam, found elsewhere in the chapter.

The next important contribution of Rozière to the knowledge of the physical and chemical constitution of the rocks is in the *Natural History* part of vol. ii., and is entitled, "A discussion on the representation of the rocks of Egypt and Arabia by prints" (*gravure*). In this discussion he commences by acknowledging the partial success that had attended the efforts of "Knorr, Buc'hoz, Schmidel, Dagoty, and Hamilton" (the latter in his work on the lavas of Vesuvius). He adds that no one before him had attempted the representation in color of primitive rocks, and adds a very strong argument for the advantages which this method of reproducing the different rocks offers.

Professor Stelzner has alluded to the confusion of the terms of syenite and granite, and the position assumed by Rozière. It may be worth while to give the exact words of the latter in the passage bearing most upon the question. He says: "Werner, who more than any other person, has introduced precision into the nomenclature, ... has proposed to restrict the term granite to those rocks composed of feldspar, quartz, and mica. . . . . He separated from these, and designated by a special name, those primitive rocks having imperfectly the texture of granite, but including, instead of quartz and mica, a large quantity of hornblende. . . . . But Mr. Werner gave to these rocks a name borrowed from the ancient authors,

that of 'syenite.' . . . . Some pieces include, beside much feldspar, a certain quantity of amphibole. . . . . But this conformity between the ancient and the new rocks is purely accidental, and I can give the assurance that they differ in every respect." Rozière quotes in support of this opinion Humboldt and Daubuisson, the latter a strong partisan of the Wernerian school. He concludes the discussion by a note of more than usual sagacity, as follows: "Many persons believe that one has done all that is necessary when one has indicated the nature of the substances which enter into a rock, and because chemistry only regards this one point, people have thought that it ought to be the same with mineralogy and geology, as if these diverse sciences had the same object, and the same methods were suitable to them all. This is an error which could only enter the mind of one who had no idea of the true end of geology." The execution of the colored plates of rock is marvellously accurate and beautiful. Plate I., Figs. 1, 2, 3, 4, and 7, of his work represent the same rock which is observed on Fig. 4, of this paper, but in different varieties. In all of them the feldspar is the most predominant mineral, and more isolated than in the representation accompanying this paper, which, however, it is only fair to say, is absolutely a faithful representation by Mr. Faber of the specimens furnished me by Lieutenant-Commander Gorringe. In Figs. 5 and 6, of Rozière's Plate I., the black (mica?) predominates, and in Fig. 8 the entire rock is green, as if from Amazon stone. In Fig. 7 the crystallized granite seems to sit upon a matrix, which looks like felsite made porphyritic (despite Rozière's assertion that no porphyries are found near Syene) by the introduction of minute black specks. In his description of these figures, Rozière invents the word *LE syenit rose*, which he says is not to be confounded with the "*LA syénite*" of the Germans. The accuracy of his observations is attested by his description of its components. He says "*le syenit* is composed essentially of rose feldspar, *mixed with smaller white crystals*, black or yellow mica, and transparent quartz of an hexagonal form more or less pronounced. Ordinarily it contains a little amphibole, ... which we can regard as accessory." It did not escape him that the large crystals of feldspar are divided longitudinally by lines which separate one part of feeble earthy lustre from another part of brilliant lustre. The justification of his two varieties of the feldspar will be found in the subsequent remarks of Delesse, the analysis of Professor Dr. Genth, and the microscopical study of Professor Dr. Stelzner. In Plate II. are eight colored varieties of feldspathic rocks, of which the last, No. 8, is described as a graphic rock with a base of pegmatite.

It would be impossible to give all the details of these magnificent plates, which compare favorably with the best examples of similar work of our own time. Plate IV., Fig. 7, represents the sandstone (belonging to the most recent formations), of which the greater part of the monuments in the Thebais were made. He gives it the name of "Psammite Quartzeux." It is a compound of small grains of quartz cemented by calcareous, and often argillaceous matter, and spotted with little dots of oxide of iron in the material of the cement. Plate V., Fig. 5, represents a calcareous stone, including a number of fossils. He describes it as a limestone, very compact, and susceptible of a certain amount of polish. He adds that he has not found a rock like it in the Libyan chain, though he cannot say that there is none; but in the Arabian chain he has found it superposed on beds of nummulites, and forming with them the formation known as horizontal limestone. Of Plate VII., Fig. 7, a tremolite, containing galena in large facets, and occurring in the neighborhood of the mountain of Barram, he says: "The ancients had established exploitations of copper and lead, of which we have found vestiges. . . . We found there the remains of furnaces which bore the marks of the most extreme heat; even the primitive rocks and gneiss which formed them bore unequivocal evidences of fusion." The remaining plates are devoted to representations of the porphyries, conglomerates, and fossils of the region between the Nile and the Red Sea. On Plate XIII. are illustrations of the rocks which he proposed to designate as "*Sinaites.*"

There are fifteen plates in all. In his mineralogical description of the valley of "Quoçeyr," Rozière treats with merited disdain the idea of Bruce and Brown, that the greater part of the obelisks were obtained from this valley, and attributes the symmetrical prismatic shape which the granite has in the mountains to the northeast of the fountains of Lambagêh to their division by cleavage. The whole work of Rozière, his facts, his manner of presenting them, his observations, and his deductions, are monuments of the permanent value which a master hand alone knows how to give to scientific investigation.

The next important contribution to Egyptian geology after Rozière, appears to be in a letter addressed by M. Lefèvre to M. Raulin, from Egypt, December, 1838, in which he makes some important additions to our knowledge [*Bulletin de la Société Géologique de France*, vol. x., p. 144 (1st series)]. The rocks from Alexandria to Syout are Tertiary, and rest unconformably on the nummulitic limestone with which the surface is undulated at certain points. This last lies above

the chalk, and is filled with nummulites. At a short distance south-east of Esueh the chalk gives place to sandstone, which continues to Syene, where they are upturned by the syenite and diorite. These syenites and diorites are of two epochs. One syenite is the older, appearing in rounded blocks, the other forming prominences which jut out of the ground, and appear to have thrown the older syenite to one side, and to be of the same age as the diorite.

Next in the order of time, and one of the most thorough and thoughtful works of all, is that entitled *On the Geology of Egypt*, by Lieutenant Newbold, of the Madras army. [Read before the Geological Society of London, June 29th, 1842.]

He finds the valley of Kosseir to have been caused by a line of fracture. [*Quarterly Journal of the Geological Society of London*, vol. iii., 1847.] In a longitudinal section of Egypt, from the first cataracts to the Mediterranean, he represents the granite as an upthrow with hypogene schists to the south and sandstones to the north. In the transverse section of Egypt, from the Libyan Desert to the Red Sea, across the valley of the Nile, in about the latitude 26° 10′ north, he represents the range of granite mountains as nearer to the Red Sea. Extensive beds of marine limestone extend from near Esneh on the south to below Cairo on the north, and from the west shore of the Red Sea across the Nile into the Libyan Desert (with occasional interruptions where plutonic and hypogenic rocks intrude). He thinks that these rocks were once continuous across the Red Sea and to the base of the plutonic axis of Sinai, from similarity of rocks and fossils. The upper beds abound in nummulites. The upper layers are different from the lower, which imbed nodular and tabular chert. Besides this, there are occasionally beds of Egyptian alabaster and stalagmitic deposits from the caverns, probably rich in fossil bones. [*Wellsted's Travels*, vol. ii., p. 123.]

He gives Ehrenberg as authority for the statement that all of the compact limestone which bounds the rocks of the Upper Nile is composed of the same animalcules as European chalk, but he prudently reminds the reader that according to the researches of Lonsdale, D'Orbigny, and Tennant, the existence of the same fossil does not identify the two beds in point of geological age. He mentions the occurrence in the limestones, and in great numbers at the foot of the cliffs, of little spheroids, encircled by a belt like the representations of a planet and its ring. They are siliceous, and are found sometimes *in situ* in a whitish marl. The Arabs call them *muktah*, or "drops." They have a thin whitish coating, and in the interior are grayish or

brownish chert. Ehrenberg called them ocellated stones or morpholites, with no trace of organic or crystalline structure, but often containing foreign bodies. Newbold next describes the sandstone, which exists in patches from the Mediterranean far into the Libyan and Nubian deserts. He accounts for this isolation by denudation, instead of ascribing it to volcanic action as d'Héricourt did. His following descriptions of the calcareous conglomerate of the shores of Egypt, and the extent and position of the post-Pleiocene, though of great interest, cannot be entered into here. He notices dikes of dolerite *sometimes imbedding iron pyrites* within and on the borders of the plutonic and metamorphic area of Upper Egypt, penetrating all the rocks from the lower sandstone to the granite. It changes sandstones into jasper, and causes deposits of chert and jasper in the limestones. Serpentines, passing into verde-antique, are met with in this area, but he thinks they are to be considered rather hypogene than trappean. He takes up the volcanic origin of the silicified wood as the hypothesis of M. Linant, and does not think it worth while to take the trouble to refute it.

The next authority, chronologically, is M. Russegger, who presented his work on Egypt, etc., in 1843; but this work has been so thoroughly considered by Professor Stelzner that I will say nothing of it here, except to record my homage to the man who could add so much of importance to what had been so recently published by the great French expedition.

Next in order are the communications of Rochet d'Héricourt, published in the *Bulletin de la Société Géologique de la France* [vol. iii., p. 541+, 1846].

His observations of the geological phenomena of the country between Suez and Cairo, and his speculations thereon, do not seem worthy of the labors of his predecessors. He sees volcanic mountains everywhere, and his explanation of the existence of a petrified forest two and a half leagues from Cairo, and his efforts to refute the fallacious theory that they were petrified while standing, because, if this had been the case, the violent volcanic shock which threw the trees down would have broken them to pieces (p. 542), can receive no notice here.

According to him, on the flank of the Mokkatam Mountain are found fossils of many species, especially lenticulites and nummulites. He mentions Débrabume, a village of Choa, as built upon a bluff of "zirconitic syenite, containing argentiferous gold." He maintains that a part of Egypt, all the Red Sea, the Gulf of Aden, the country

of Adel, and the kingdom of Choa, are the results of volcanic activity. All the specimens which he brought home to France were lavas, obsidians, basalts, and trachytes. Not much assistance is to be obtained from him.

M. Delesse is the next to increase our knowledge of the geology and lithology of Egypt, in a communication to the Geological Society of France [*Bulletin de la Société Géologique de la France, Sur la Syénite rose d'Egypte*, by M. H. Delesse, vol. vii., p. 484, 1850], of the translation of which into *Karsten's Archiv* Professor Stelzner has made excellent use. It is to be remarked that Delesse does not accept the "*le syenit*" of Rozière, but goes back to the *la syénite*. He agrees with his predecessor and compatriot that this syenite contains much more quartz than the rock properly so called, and that the hornblende is "accidental." He preserves the name of syenite, though many of the specimens brought from Egypt by Lefèbre (*sic*) are only granites, and not even amphibolic (p. 485). This characterization, and the list of constituents which follows, thoroughly justifies Professor Stelzner's designation of the rock: "The rose-colored syenite of Egypt is composed of orthose, of oligoclase, of mica, and often of hornblende."

He notices a remark of Mr. Newbold worth bearing in mind, that the dry, hot climate of Egypt is much better adapted to preserve the granitic rocks from decomposition than (even) the climate of India. He alludes to the fact, insisted upon by Russegger and Lefèvre, that the syenite of Egypt is traversed by numerous dikes of diorite, which latter were exploited by the Egpytians (*Russ.*, ii., pp. 320, 323, 326, etc.). He mentions that he has always found a similar synthesis in the Vosges, and suggests that the presence of the hornblende in the *syenite* may be intimately connected with the juxtaposition of the *diorite*. The kind of transparent glaze which these rocks have been observed to show, when exposed to the action of the water, he takes to be due to the solution of quartz by the water traversing the granites, and by the high temperature of the water. In the Louvre are seen specimens of carving in the rock, which show the polish was unaltered under the pure sky of Egypt, even after 4000 years of exposure. Pompey's pillar, Cleopatra's needle, the great sanctuary monolith of Säis, and the *interior* of the great pyramid of Cheops, are built of it.

M. Bellardi communicates a list of 118 nummulitic fossils from Egypt [*Bulletin de la Société Géologique de la France*, vol. viii., p.

261, 1851], per M. d'Archiac, which serves to show how frequently the nummulitic limestones are found in that country.

In the same volume is found Daubrée's note on the presence of zircons in the granites and syenite of the Vosges (p. 346). He finds zircons associated with titaniferous iron ore at Andlau and Barr (Bas Rhin), and in the streams that cut through the syenite of the Hohwald in the valley of the Andlau. He finds a great resemblance between these and those mentioned by Dufrenoy as occurring in the auriferous sands of California, of New Grenada, of the Urals, and of the Rhine. To make the resemblance more complete, he found in the sand of the Mosel enough flakes of gold to pay three centimes for a day's work in washing them.

This existence of zircons in the granites of the Vosges, added to what we know of their occurrence in Scandinavia and the United States, makes their discovery in the Egyptian rock of greater interest.

Finally, for this paper at least, in his interesting books *Aus dem Orient* (Stuttgart, 1867), Oscar Fraas confirms the observations of some of his predecessors as to the mountains on either side of the Red Sea, and compares them to the Vosges and Schwarzwald on the Rhine. The Sinai chain (Arabia) has along its eastern flank, as the African chain below the Nile and Red Sea on its western flank, newer rocks, but of the latter, those which are most interesting in this connection are composed of the Chalk and the Tertiary (*i. e.*, Eocene). The land between the Nile and the Red Sea is unpopulated. No rain falls, and deposits of salt are not infrequent. Daily caravans are sent from Cosseir (Kosseir, Quoçeyr) to the mountains for water.

Climbing the Atágah, near Suez, the chain consists of calcareous rock cleft in vertical walls, the cleavage planes running south. They rise like steps of about 2½ feet, in which the sedimentation is seen to be more or less parallel. The outside debris is 2 kilometers wide. One-third of the way up is a broad step, 2½ kilometers wide, caused by softer argillaceous terraces. Nummulites, oysters, anthophyllæ, etc., are a sure guide to the eocene character of the rock. In the main, the fossils are similar to those of the basin of Paris. The building-stone of Cairo is nummulitic limestone from Mokattan,* and the Sphinx on the other side of the Nile is made of it.

From these citations from all the principal authorities on Egypt, it will be seen that the shafts of most of the obelisks were cut from the red granite, found principally in the Mountains of the Chain,

* The spelling of Egyptian words by Europeans is very variable.

and especially where these mountains are pierced by the Nile in the vicinity of Syene, because the greatest facilities were here offered for their transportation with the minimum amount of labor, northwards to Middle and Lower Egypt. Secondly, the rocks which form the foundation steps of the New York obelisk, were taken from some of the innumerable quarries of nummulitic limestone, near where the obelisk was first erected, *i. e.* Heliopolis. Thirdly, the copper which entered into the bronze casts, which will be described further on, may have been obtained from one of the copper mines mentioned by Rozière and others in Egypt, and must have been the result of an intelligent series of metallurgical operations having the production of this alloy in view.

Where the tin (of the bronze) came from is not so clear, but whether from the British Isles or elsewhere there is no doubt that it was added in definite proportions, with a knowledge of the advantages derived from its combination. It is of less importance to trace the sources of the mortar which Prof. Richards's two analyses show to contain gypsum or alabaster, as this substance as well as chert is shown by Newbold to be of frequent occurrence in the tertiary limestone. One of the above analyzed specimens is largely composed of gypsum, though this may be accidental, as the amount of material furnished for analysis was extremely small.

THE RED SYENITIC GRANITE OF THE SHAFT.

This rock is of a general pinkish hue when viewed from a distance, and on nearer approach reveals the irregular mottling of pink, black and white, admirably rendered on the accompanying plate, Fig. 4. It is almost impossible to render, by a flat print, the translucency or that vivid effect produced by both lustre and color, but the attempt here is a very close approach to nature.

The first thing that strikes one is the freshness and soundness of the rock. No "maladie de granite" is observable, and this fact will answer the first and natural question as to why this rock was so much preferred by the Egyptians for monumental purposes.

The writer made a number of careful determinations of its specific gravity, first in lumps as more applicable to questions of transportation, etc., and afterwards in powder, to determine by comparison the porosity of the rock.

The specific gravity of the rock as it is, *i. e.* with all the cavities it contains, is 2.6618, but broken up to the size of a pea the quartz pulverizes, except in the interior of the small masses, and the specific gravity becomes 2.7188. It would, perhaps, rise to 2.75 or 2.76 if completely pulverized, but this is unimportant unless it be to

determine approximatively how much of the desert sand is composed of the old granite, and how much of the newer and generally lighter rocks. A cubic foot of the rock weighs 166.1625 lbs. av.

An independent series of experiments was made by Prof. G. W. Wigner, and published in the *Analyst*. By these the specific gravity of the syenite was placed at 2.682.

The absorbent power of the unchanged stone was at the rate of 5.440 grams of water per square meter; the weathered surface showed an absorbent power six times as great. After powdering the stone and separating the constituent minerals by the Sonstadt solution the result was as given below.

Alongside of this separation by the Sonstadt solution, is placed an estimate of the relative volumes of the different constituents of a similar rock, based by Delesse on the careful measurement of the areas of these constituents as defined on polished surfaces.*

	Prof. Wigner. In 8.328 parts		p.c.	Delesse. p. c.
Mica, ...	2.986	=	36	4
Quartz, ...	2.747	=	33	44
Feldspar, ...	2.595	=	31	52
			100	100

The proportion of mica varied considerably in different parts of the stone.

The following are the analyses of Prof. Smith, compared with those of Delesse and of Dr. Genth.

	WHOLE ROCK.		FELDSPAR.		MICA.
	Delesse.	Smith.	Genth.‡	Smith.	Wigner.
Silica (SiO_2), ...	70.25	68.18	62.42	63.38	46.16
Iron Sesquioxide (Fe_2O_3),	† 2.50	4.10	23.75 (with Alumina)	22.25 (with Alumina)	7.30
Alumina (Al_2O_3), . . .	16.00	16.20			41.18
Lime (CaO), ...	1.60	1.75	4.62	1.09	. . . . . .
Magnesia (MgO), . . .	9.00 (Magnesia, Soda, Potash)	0.48	. . . . .	0.45	6.77
Soda (Na_2O), ...		2.88	9.21	1.84	0.92
Potash (K_2O), ...		6.48	. . . . .	10.66	5.24
Manganese Oxide, . . .	. . . . .	(trace)	. . . . .	. . . . .	. . . . . .
Ignition, ...	.65	. . . . .	. . . . .	. . . . .	. . . . . .
	100.00	100.07	100.00	99.67	107.57 (?) §

* See also Delesse's physical analysis of this granite in Dr. Stelzner's paper.

† Containing manganese, which is given separately by Prof. Smith as a trace.

‡ This is the estimated analysis of the *pure oligoclase;* Prof. Smith's analysis is doubtless of both kinds mixed.

§ There must be an error in the percentages as given by the authority from which this is taken.

Dr. F. A. Genth, Professor of Chemistry of the University of Pennsylvania, at my request, separated under the microscope and analyzed the feldspars of this granite with the results given below. He writes:

Feldspar from the Granite of the Obelisk.

"White with delicate striation. It was impossible to obtain it entirely free from quartz and in sufficient quantity for a complete analysis. The pieces which I could pick out contained:

	p. c.
Silicium oxide,	66.70
Aluminium oxide,	21.40
Calcium oxide,	4.17

"These percentages indicate this feldspar to be oligoclase. Calculating from the calcium oxide, the requisite amount of aluminium oxide and silicium oxide for a calcium oligoclase, and from the remaining aluminium oxide, the required sodium oxide and silicium oxide for sodium oligoclase, there are in 100 parts,

	Mixture of quartz and oligoclase.	Pure oligoclase.
Quartz,	9.87	...
Silicium oxide,	56.26	62.42
Aluminium oxide,	21.40	23.75
Calcium oxide,	4.17	4.62
Sodium oxide,	8.30	9.21
	100.	100.

which corresponds exceedingly well with the oligoclase analyses on record."

A specimen of this granite was sent to Prof. A. J. Julien, who made three thin sections of it. Two of them were selected for representation, together with a thin section of a specimen of syenite from near Germantown, of different texture, for comparison. These three thin sections were drawn and painted under my inspection from their images in the polarizing microscope by Mr. H. Faber, of Philadelphia, and afterwards submitted to Dr. Alfred Stelzner, Professor of Geology in the Royal Saxon Mining School. The lithographic work was done by Sinclair & Sons, of Philadelphia. The following is Dr. Stelzner's report:

ON THE BIOTITE-HOLDING AMPHIBOLE-GRANITE FROM SYENE (ASSUAM).

BY PROFESSOR ALFRED STELZNER, PH.D.

The handsome stone of which the ancient Egyptians, and after their time the Romans, made such splendid use for monumental and architectural purposes, is known to-day in commerce as "Red Oriental Granite."

We have valuable information concerning its occurrence, among others, from Joseph Russegger.* According to him the "Oriental granite" forms the principal mass of several parallel chains which stretch from the east Egyptian coast range (that is from the Red Sea) westwards through Egypt and Nubia, and only on the other side of the Nile in the Libyan desert are lost under a covering of more recent sedimentary rocks. Numerous dikes and isolated masses of diorite and porphyry† intersect these granitoid chains, which, in consequence of more or less deep-seated weathering, are covered on their bold and knolly surfaces to a great extent with rock-labyrinths and gigantic blocks.

Another very remarkable phenomenon, in which Russegger likewise sees a kind of decomposition—the result of a long exposure to the combined influence of the water and the atmosphere—is this, that the outside of the granite blocks, and generally of the granite rock itself, is covered with a very thin, dark black, highly lustrous coating, which gives it the appearance of having been painted over with pitch. Russegger reports this coating as so thin, and so intimately mixed with the mass of the rock, that it cannot be separated from the latter, and he takes this material to be ferrous oxide.

According to the descriptions at hand, the structure and composition of the "Oriental granites" are very variable. Coarsely granular varieties, made porphyritic by orthoclase crystals which are distributed

* Travels in Egypt, Nubia, and the East Indies with special reference to the natural history relations of the respective countries; undertaken in the years 1836, 1837 and 1838, vol. ii., part i., Stuttgart, 1843. The work of Rozière, Descrip. minéral de la vallée de Kosseir in the Mémoire sur l'Egypte, III., p. 227, was unfortunately inaccessible to me.

† Among the porphyries, the most interesting is that of "Dschebel Dochân," or the "Mons Porphyrites" of the ancients, which produces the beautiful red porphyry (pórfido rosso antico) which was widely spread over the entire old classic world. Russegger, l. c., 351, 356.

without regularity in the main mass, seem to be the most usual. They occur immediately in the neighborhood of Syene (Assuam). Out of these are developed locally (for instance, on the road along the cataracts of Syene) such coarsely granular masses, that the individual feldspar and quartz constituents reach the size of a cubic foot; in other places, the size of the grains diminishes, and then there results by a parallel arrangement of the scales of mica a gneissoid rock. Among the varieties of composition three are especially given. That which seems to be most widely distributed is an amphibole-granite, containing biotite, in the composition of which, orthoclase, oligoclase, quartz, amphibole, and biotite take part. Some of the principal localities for this are the old quarries near Syene, and, besides this, Djebel Gareb and Djebel Ezzeit. This principal rock, by the gradual diminution of its hornblende, either merges into normal biotite-granite, which may be either rich in mica (east side of the hill on which the town of Syene is built), or poor in mica (Debu); or it passes, by disappearance of its quartz and the predominance of its hornblende, into normal syenite. Russegger satisfied himself in various localities that one of these rock-varieties developed itself very gradually out of the other, and in such a way that in the mountain chain of the cataracts of Syene he was not able to separate one from another. Also, on the east edge of the "Waddi-el-Hammer," he observed that the granite became fine-grained, and, by visible diminution of the quartz, passed into syenite, which latter seems generally to become more frequent towards the east.

In the above lines I have used, for the varieties of rocks, those names which, at present, are more common among German petrographers; nevertheless, as these names, until recently and, perhaps, even now, have not won universal acceptance, and as the different appellations of the rocks under consideration are derived from just the above-indicated variations, which are to be observed in Egypt, it may be worth while to introduce a few historical remarks.

A. G. Werner, the founder of the present geology, defined with precision, for the first time, the nearly arbitrarily employed names of rocks. In his "short classification and description of the different kinds of rocks," Dresden, 1787, he defines granite as a "mixed rock, which consists of feldspar, quartz, and mica, which are so united together in a granular network, that every part of the mixture penetrates and is attached to the rest."*

* "Welche in einem körnigen Gewebe so miteinander verbunden sind dass ein jeder Theil des Gemenges in und mit dem Anderen verwachsen ist."

In the following paragraph (7), he describes, in conformity with the above definition, "a kind of granite, which appears to be a particular species of rock," because it "contains hornblende in its mass, partly together with mica, partly in place of mica." If a more general occurrence of this kind of rock (which at first was only known near Dresden and in the eastern part of Saxony, Oberlausitz) should be proved, "a special name must be given to it, and it might be called greenstone." Shortly afterwards, it appeared that these rocks, rich in hornblende, had quite a wide distribution, and Werner himself became acquainted with them, even, for example, from Upper Egypt. This latter circumstance evidently caused him to deviate again from his original proposition, and to give to this hornblende-carrying granite the name of syenite, which already was employed by Pliny (36.13).* Werner, therefore, understood by syenite mixtures of feldspar and hornblende, *both with and without quartz.*

As, however, in the further development of petrography, a sharper division between the acidic and basic rocks proved to be desirable, the German geologists designated the quartzose varieties of Werner's "syenite" as syenitic granite or amphibole-granite, and used the name syenite exclusively for the mixture of orthoclase and hornblende free from quartz. This is, to-day, in Germany, the usual terminology.

Rozière followed a different course. He believed that the name syenite must be given to that rock which is found near the cataracts of the old Syene (Assuam), and in which the old Egyptians had located their great quarries. But this stone, as was mentioned above, contains quartz. For its corresponding modification, which was free from quartz, Rozière proposed the name *Sinaite,* because in the mean time it had transpired that along with others it occurs on Mount Sinai. The French, English, and North American geologists, for a long time, followed at least the first suggestion of Rozière, and have generally called the "amphibole-granite" of the Germans *syenite;* on the other hand, the second proposition of Rozière has nowhere received any continuous acceptance;† the feldspar-hornblende mixtures, free from quartz, have been called sometimes diorites, and sometimes greenstones, by the French,

* Köhler, Bergmännisches Journal, 1788, ii., 824.

† As little has the name of hypo-syenyte, proposed by Dana, for a mixture of orthoclase and hornblende free from quartz, been able to graft itself on the terminology.

English, and North American petrographers, without regard to the particular monoclinic or triclinic character of their feldspar.*

Thus, a very unfortunate confusion arose, which, only recently, has shown signs of abatement, and that too, it must be said, by the adoption of the German terminology. I follow here this latter, and need fear no misunderstanding, if I again mention that in Upper Egypt amphibole-granite is the predominating rock, but that both biotite-granite and syenite are found there.

The amphibole-granite was employed with especial preference by the Egyptians for ornamental and architectural purposes; according to Delesse, the inside (and outside†) (?) of the great pyramids of Cheops consist of it, as well as the numerous sphinxes and sarcophagi, Pompey's pillar, the sacred monolith of Säis, and the needles of Cleopatra.

We have an extremely careful description of this Egyptian amphibole-granite (syenite of Rozière) from the distinguished French geologist, A. Delesse, whose death science has very recently had to mourn (24, iii., 1881).

As the New York needle consists of this rock, I consider it desirable to give the more important observations of Delesse concerning it.

According to him, the rock consists of quartz, orthoclase, oligoclase, mica, and often, also, of hornblende.‡

"The quartz is translucent and gray; it has occasionally a somewhat violet or smoky-gray tint, which, as in the case of the quartz of protogine, is derived from a small quantity of organic matter. The orthoclase has a beautiful bright-red, red, or yellowish-red color, which reminds one of the coloration of the orthoclase in the syenite of the Vosges, but is much brighter; it forms crystals of several centimeters in length, twins as in the case of granitic rocks; it generally is the most prominent constituent of the mixture, is very often the mineral most largely represented, and generally gives the rock its reddish color." (See Plate, Fig. 4.)

Delesse found the specific gravity to be 2.568. At a red heat, it loses only 0.35 per cent. This loss is very little, as is generally the case with orthoclase.

* D. Forbes, The Study of Chemical Geology, London, 1868, 10.

† In the original memoir of Delesse, elsewhere cited, only the inside of the pyramid is mentioned.—P. F.

‡ Delesse, On the Light-red Syenite from Egypt, in Karsten's and v. Dechen's Archiv. for Mineralogy, Geology, Mining, and Metallurgy, Berlin, 1851, xxiv. 63–70.

When the feldspar decomposes, it sometimes assumes a brown color, which is due to a little manganese oxide contained in it, and which is set free.

The triclinic feldspar has not a greasy lustre, as in the syenite of the Vosges, and appears to be oligoclase. It is commonly white, sometimes it is yellowish, or even greenish, as, for instance, in some specimens from Syene, in which it occurs very largely, and even exceeds the orthoclase in quantity.

The mica, rich in magnesia and iron, forms brilliant scales mostly of black color, but, according to Rozière, is also sometimes brown and green. When its color is black, it is not distinguishable from that of the hornblende which is often united with the mica.* Also some pyrite and, as in all hornblende-granites, some magnetite occur in it.

Garnet is found in it (but very infrequently), of a dark-brown color, and crystallized in the usual form of the rhombic dodecahedron.

According to his method, described in the *Annales des Mines* (4th Serie, t. xiii., p. 379), Delesse determined the relative volumes of the different minerals which appeared on the surface of a polished fragment, and found: red orthoclase, 43 per cent.; gray quartz, 44 per cent.; white oligoclase, 9 per cent.; black mica, 4 per cent.

This piece, which was very rich in quartz, seemed to contain no hornblende, but it contained, notwithstanding, less orthoclase, and especially less mica, than from its appearance would have been supposed; furthermore, this optical deception is general, and is to be ascribed to the fact that the minerals which possess bright and lustrous colors, like the bright-red feldspar, and especially the mica, attract the attention much more than the quartz of gray or dull color.

Delesse undertook an analysis of an Egyptian granite, by grinding up a large piece from the Egyptian Museum of the Louvre, which M. Dubois, one of the conservators, had placed at his disposal; it exhibited the same characteristics as those mentioned above, but some hornblende was observable in it.

Delesse found the following constituents:

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* Russegger, whose communications on the rock of the quarries of Syene (Assuam) agree well with those of Delesse, says "Hornblende forms an accessory constituent, with the increase of which the mica decreases and the familiar transition into syenite is established." Hornblende and biotite can thus replace each other.

Silicium oxide (SiO_2),	70.25	per cent.
Aluminium oxide (Al_2O_3),	16.00	"
Oxide of iron containing manganese,	2.50	"
Lime,	1.60	"
Alkalies and magnesia (by loss),	9.00	"
Loss by ignition,	.65	"
Total,	100.00	"

He thus summarizes the result of his investigation: "It appears that the chemical constitution of the Egyptian syenite does not vary in important respects from that which I have found for several granites. Since it contains, as I remarked in the beginning, a great deal of quartz, it can be regarded as a hornblende-granite, or as a rock species which forms a transition from the granite family to the syenite family."

This result, therefore, corresponds perfectly with the nomenclature used in Germany, and also with that which I set forth at the commencement of this paper.

At the time that M. Delesse wrote the above remarks, the microscope had not yet established its home on the work-table of the petrographer.

I have carefully examined the thin sections which were made from the rock of the New York needle, which Professor Frazer handed me. The results which have been attained by the employment of this new method of research, and which I give in the following lines, may be regarded as a continuation of the remarks of the French savant.

At the first glance under the microscope it is apparent that the biotite-holding amphibole-granite of Syene has a thoroughly crystalline granular structure. Its principal components, however, are almost never crystals perfectly developed on every side, but possess generally the form of fragments; yet for these Werner's old description holds perfectly good, that "every part of the mixture penetrates and is attached to the rest."

As an exception, two small and quite isolated parts of one of the sections show somewhat of a granitophyr structure; an extremely fine permeation of feldspar and quartzlike graphic granite.

The important elements of the rock are microcline, oligoclase, quartz, and amphibole, with which some biotite is associated.

The microcline is the constituent mentioned by Delesse as red orthoclase. It is very fresh and free from interpositions; between

the crossed Nicols it shows in an exceptionally beautiful manner, in the sections parallel to the basal plane, the "grating" structure dependent upon its peculiar lamellar construction. On those sections which are parallel to the brachypinacoid, a simpler flame structure is observable. Figs. 1 and 2 give a good idea of the splendid bright picture which the observer of these thin sections obtains in the polarizing microscope.

The OLIGOCLASE shows on its basal sections, in contrast to the microcline, only one fine but very apparent twin striation parallel to the edge PM (see Fig. 2, right hand lower part). It is also free from interpositions, but less fresh than the microcline, and in the vicinity of clefts which intersect it, has a mealy opacity. That this is really oligoclase, Delesse had already made probable, and the analyses of Professor F. A. Genth add additional confirmation to this hypothesis.

Some isolated grains of feldspar have become in consequence of advancing decomposition perfectly opaque. Whether these also are to be reckoned as plagioclase, or whether they are to be considered as orthoclase, I am not able to decide from the two sections before me.

The QUARTZ occurs partly in large individual grains, partly in fine-grained aggregates. These latter have the form of veins, and cross between the fragmentary shattered larger feldspar and quartz constituents. There is, therefore, here, the *mortar* structure described by Törnebom, as characteristic of the Swedish granites, and which, according to his views, is characteristic of the oldest, but is wanting in the later granites.*

The larger quartz grains belonging to the first separation are irregularly shaped, as has been already remarked. They contain a considerable number of fluid cavities, which, to a certain extent, are arranged in the well-known cloud-like zones. The bubbles of the larger liquid inclusions are immovable, those of the smaller, on the other hand, show invariably a greater or less movement. Besides this, the quartz contains a few small reddish translucent scales of hematite (either hexagonal or distorted to rhombs); also in one of its grains are to be seen an infinite number of hair-like black needles lying confusedly over each other. In ordinary light the sections of the quartz grains are clear as water; but between crossed Nicols they shine in monochromatic bright colors (Fig. 2, below).

* Naagra ord om granit och gneiss in Geol. Fören. Stockholm Förh., Bd. v., 233. An excerpt from this in the *Neues Jahrbuch für Mineralogie*, 1881, II., -50-.

In one of the two thin sections under consideration, there is accidentally a quartz grain which has been cut parallel to its base. This remains in all horizontal positions dark, and shows a very perceptible interference cross when the eye-piece is pulled out.

The HORNBLENDE occurs in prismatic but otherwise irregularly defined individuals. It is quite fresh, and in ordinary light green and translucent. Tested with one Nicol it shows in the direction of the axis of elasticity, *c*, a very powerful absorption.

The small angle between the axis *c* and the maximum of extinction, and the very apparent obtuse angles of the cleavage lines characterize this mineral in an exceptionally perfect manner.

BIOTITE occurs in single large, brown, translucent scales. The transverse sections show the usual lamellar structure, and, by the employment of one Nicol prism, the strong absorption of the ordinary ray of which the vibrations are perpendicular to *c*.

Beside the above, considered essential constituents in the composition of the rock, the following accessory minerals also associate themselves in it, though it must be confessed, in a very subordinate manner. Of primary origin, titanite, apatite, magnetite, and zircon. Garnet and pyrite, mentioned by Delesse, are not contained in the sections before me.

TITANITE is found in both sections in numerous small, yellowish-red, translucent grains, which, together with a very pure constitution, show an irregular outline.

The APATITE occurs in excessively fine, water-clear, acicular crystals.

The MAGNETITE appears in the form of opaque, partly irregularly bounded, and partly octohedrally crystallized grains.

Finally, there are four small crystals of ZIRCON in one section, and six in the other. When they lie parallel to the plane of the thin section, one can convince himself that they are of prismatic habit, and that both poles are terminated by pyramidal planes; in other positions one sees small square transverse sections. The little prisms are 0.13 to 0.16 mm. long, and have diameters of from 0.03 to 0.05 mm.

Secondary formations are almost entirely wanting in the sections before me; in only two places appear a little viridite and yellowish-green translucent needles of pistazite.

The rock of the needle can, therefore, be regarded as unusually fresh and "healthy," in spite of the honorable age which it possesses.

Amphibole-granites, which have a like, or, at least a similar constitution to that of Syene, are rocks of frequent occurrence; thus, amongst others, Ferdinand Zirkel has made known numerous American localities, as for example, from the north end of Truckee Range; from the Pah-tson Mountains; from Agate Pass; Cortez Range, Eagon Cañon, Nevada; Cottonwood Cañon, in the Wahsatch Range, etc.; and, moreover, according to the determination which Clarence King and his associated geologists have set up, they appear at all these points to be later eruptive rocks.*

In Europe, rocks of this kind under discussion are known, for instance, from Odenwald, from the Vosges, and from Scandinavia.

Since F. Zirkel,† with reference to the North American, and H. Rosenbusch,‡ with regard to the European amphibole-granites, have called attention to the fact, that all these amphibole-granites contain titanite so constantly that the latter should be reckoned as one of their characteristic accessory constituents, it is not without interest to observe that the Egyptian rock conforms to the experience gained elsewhere.

Professor Frazer has added to the plates of thin sections from the monolith a third, prepared from a rock in the vicinity of Germantown, in the city of Philadelphia. I have also examined this section, and must confess that, as regards the nature of its constituents, the Germantown rock is very similar to that from Syene, but, on the other hand, differs from it by a somewhat different relation to each other of the constituents, and also in its more finely granular structure.

In conclusion, the following is a short diagnosis of the Germantown amphibole-granite (or amphibole-gneiss), of which a colored representation in polarized light is given in Fig. 3.

Its essential constituents are microcline, plagioclase, orthoclase (?), quartz, hornblende, biotite, and some muscovite.

The MICROCLINE and PLAGIOCLASE are both still very fresh; the few feldspar grains, which show no twin striation, may possibly be orthoclase.

QUARTZ occurs only in rounded grains, and much more sparsely than in the Egyptian rock. It is almost free from interpositions;

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* F. Zirkel, Microscopical Petrography, in the United States Geological Exploration of the Fortieth Parallel. Washington, 1876, 39.

† Ibid., 58.

‡ H. Rosenbusch, Microscopical Physiography of the Massive Rocks. Stuttgart, 1877, 22.

even fluid bubbles are only to be observed in certain places, and exhibit very small dimensions. The green translucent hornblende is in greater quantity than the brown biotite, in addition to which also large isolated scales of muscovite and very fine scales of a green micaceous mineral are observable.

Among the accessory constituents of the rock from Germantown, must be mentioned also here again, in the front rank, titanite, though in this case it occurs in numerous small rounded crystals. Finally, there are in the section before me, a couple of very small prismatic crystals, which, in consequence of their high refractive power for light, I should again take for zircons. Magnetite or particles of other ore are entirely absent from the Germantown rock so far as I can judge.

A. STELZNER.

FREIBERG, 24th December, 1881.

NOTE.—Among the numerous localities given by Dr. Genth, in his Mineralogy of Pennsylvania, for the occurrence of zircon, most of them too in or near the Philadelphia belt, none in syenite has yet been mentioned, nor any locality nearer to the city than fifteen miles. It is very probable, however, that a search for this mineral would result in the discovery of its existence very generally through the amphibole-gneisses and granites of this vicinity, but generally in very minute crystals.—P. F.

In the first part of this paper the limestones have been described in the words of the geologists Rozière, Newbold, Russegger, d'Héricourt, and Fraas. All agree that the limestone, which forms the bluffs near Cairo and lines the Nile, is "above the Chalk." No true position in the series is more definitely defined by the last-named traveller, who pronounces it of Eocene age. Dr. Genth called my attention to a fossil taken from a part of "Specimen 2," of Lieutenant-Commander Gorringe's series, which was identified by Dr. Joseph Leidy as a nummulite, in which view Geheimrath Dr. Geinitz, of the Royal Saxon Natural History Museum, in the Dresden *Zwinger*, concurred. Its geological age is thus well known, but as to the particular quarry whence it was taken, it would be impossible to state this, as there are so many. If the obelisk was originally erected at Heliopolis, it is probable that the limestone for the steps was quarried not far off.

A list of works on the subject of obelisks may fitly terminate this paper.

The following list gives the titles of such works, both ancient and modern, together with a number which corresponds with that placed opposite each volume in the catalogue of the Bibliothèque Nationale de France. This latter may be found convenient by those who desire to consult any of these works while in Paris.

LITERATURE ON THE SUBJECT OF OBELISKS.

Nouveau Manuel de Bibliographie Universelle.

1. *Obélisque Petrii Angelii Bargarel.* Commentarius de obeliscis, Roma, 1546, in 4. Found in Græviis, Antiquitatum Romanum, vol. iv., p. 1893, in fol.

2. *Mic. Mercati,* degli obelischi di Roma, 1589, in 4.

3. *Domen Fontana,* Della transportatione dell' obelisco Vaticano, etc. Roma, 1590, in fol., avec fig.

4. Athen. Kircher. Obeliscus pamphilius, etc. Roma, 1560, in fol.

5. Kircheri. Obelisci Ægyptiaci interpretatio. Roma, 1666, in fol.

6. Giovano Jacomo Rossi, Nova raeolta degl' obelischi . . . . del alma citta di Roma. Roma, vers 1651.

7. Des Obélisques, par *Ponchard,* Histoire de l'Acad. des Inscrip., p. 193–198.

8. Castelli et ponti, di *Nic. Zabaglia,* con la discrizione del trasporto dell transporto dell obelisco vaticano di altri. Domen Fontana. Rom. 1743, gr. in fol.

9. *Angelo Maria Bandino.* De obelisco Augusti Cæsaris, e Campi Martii, ruderibus nuper eruto commentarius. Roma, 1750, in fol.

10. Question historique sur le sujet d'un ancien obélisque. (Voyez continuation des Mémoires de littérature de Sallengre, vol. xi., pp. 473–478.)

11. Observations de Gibert sur l'obélisque interpreté par Hermapion. (Mem. de l'Acad. des inscrip., vol. xxxv., pp. 665-676.)

12. Georg Zolga. De origin et usu obeliscorum. Roma, 1797, gr. in fol. (ouvrage curieux).

13. Expédition du Louxor; ou, Relation da la campagne faite dans la Thébaide pour en rapporter l'obélisque occidentale de Thèbes, par *J. P. Angelin,* 1833 in 8vo. [7561.]

14. L'Obélisque de Louqsor à Cherbourg, par *A. de Berrager,* 1833, in 8 (c est une notice).

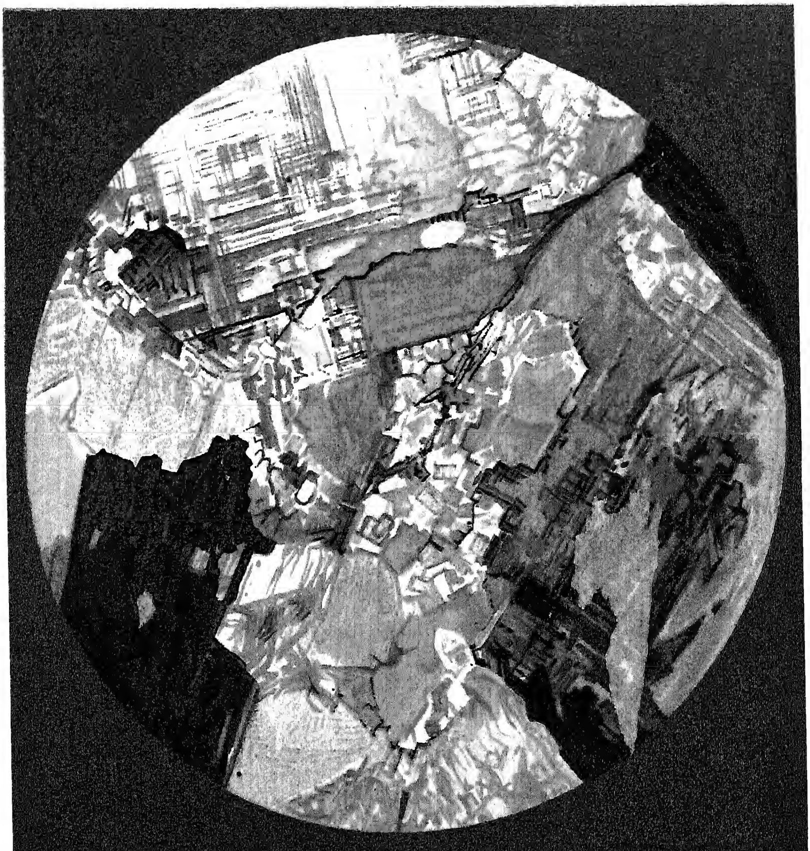
15. L'Obélisque de Louqsor transporté à Paris. Notice histor., descrip., et archæol. sur ce monument, par M. Champollion, avec la fig. de l'oél. et l'interpret. de ses inscrip. hiéroglyph., d'après les dessins et les notes MSS. de Champollion, jeune. Paris, 1833, in 8vo. [7563.]

16. L'Obélisque de Luxor au terreplein du Pont Neuf, la statue de Henri IV. à la fontaine de la Place Dessaix. 1833, in 8vo. [7565.]

17. Descrip. des obélisques de Louqsor, figurés sur la Place de la Concorde et des Invalides, et précis des opérations rélatives au transport d'un de ces monuments dans la capitale, lue à la séance publique de l'Institute, 2 Août, 1832, par Alex. Delaborde. 1833, in 8vo. [7559.]

18. Sur l'emplacement de l'obélisque de Louqsor. Paris, Decourchant, in 8vo. [7564.]
19. Nouvelle descrip. des obélisques de Louqsor, augmentée des renseignements les plus récents et précédée d'un coup d'œil sur l'Egypte moderne. 1833, in 8vo. [7560.]
20. Erection de l'obélisque. 1836, in 4to. [7580.]
21. L'Obélisque de Louqsor, érigé sur la Place de la Concorde, le 25 Oct., 1836. *A. Lebas.* 1 pl., in 4to. [7581.]
22. Sur l'obélisque de Louqsor, et les embels. de la Place de la Concorde. Extr. de constitu. Dec. 14, 1834. [7568.]
23. L'Histoire de l'obélisque de Louqsor, etc. [7574.]
24. Notice historique sur l'obélisque de Louqsor. Paris. Bonnet, in fol., plan. [7582.]
25. Histoire véritable de l'obélisque de Louqsor, depuis sa naissance jusq'a nos jours. Par un Egyptien. Paris. Chassigny, 1837, in 12mo.
26. Memoire de l'obélisque de Louqsor, écrit par lui-même. Paris, 1836. [7578.]
27. L'Obélisque de Luxor. Histoire de sa translation à Paris; déscription des travaux auxquels il a donné lieu, etc. *A. Lebas.* 1839, in 4to. [7573.]
28. Obélisque Egyptien de Paris, d'après les dessins faits à Louqsor, in 1829, par Champollion, le jeune. 1836, in plano. [7577.]
29. L'Obélisque de Louqsor. Pamphlet par Petrus Borel. 1836, in 8vo. [7579.]
30. Nouvelle disc. de l'obélisque de Luxor, et de son piédestal, son élévation sur la Place de la Concorde, et nouveau plan de cette Place. 1826, in 4to. [7570.]
31. Descrip. de l'obélisque de Luxor, et de son piédestal, etc. 1849, in 4to. [7562.]
32. Interpretatio obeliscorum, urbis digesta, par A. M. Ungavellium. Roma. 1842, in fol., avec fig.
33. *A. G. Ballin.* Notes sur les obélisques de Rome, particu. sur ceux de la Villa Torlonia, sur les Lux., etc. Mems. ins. dan l'Academie Royale de Rouen. 1844, in 8vo.
34. *Nestor Lhote.* Notice histor. sur les obélisques Egypt., et en particulière sur l'obélisque de Louqsor. Paris, 1848, in 8vo. [7572.]
Besides, these:
35. Millin. Dict. des Beaux Arts, article *Obélisques.*
36. *Benj. Tudelensis.* Itinerarium Hebraice, etc. Lugd., 1633, in 12mo.
37. *Petrus Martyr de l'Anglesia.* Legatio Babylonica, 1533.
38. *Ramusio.* Les Navigationes e Viggi. (Venezia, 1563.)
39. *Prosperi Alpini.* Ital. rerum Ægypt., libri iv. Lugd. Batavor., 1755.
40. *Luys del Marmol Carvajal.* Descrip. gen. de Africa, en Malaga, 1599.
41. *Manuel d'Almeyda.* Hist. gen. de Ethiopia, etc. Abbrev. par P. Tellez. Coimbra, 1660.
42. Relation d'un voyage en Ethiopie, 1700.
43. *Franc Genellio Carveri.* Giro del Mondo. Venezia, 1719.
44. *Dominique Jauna.* L'état présent de l'Ægypte. Leyde, 1747.
45. *Van Egmont et Joh. Hayman.* Voyage en Europe, Asie, et Ægypte. London, 1759.
46. *Granger.* Relation d'un voyage fait en Ægypte. Paris, 1745.
47. *Paul Lucas.* Dif. voy. de Paris, 1704, 1712, et Rom., 1724, in 12mo.
48. Lettres dif. et curieuse. Paris, 1704.
49. Nouveaux men. des missions jesuites dans le Levant, vols. ii., v., et vii. Paris, 1718, 1725, 1729.
50. *Fred. Louis Norden.* Voyage d'Egypte et de Nub., edit. de Langlis. Paris, 1795, in 4to.

Fig. 1.

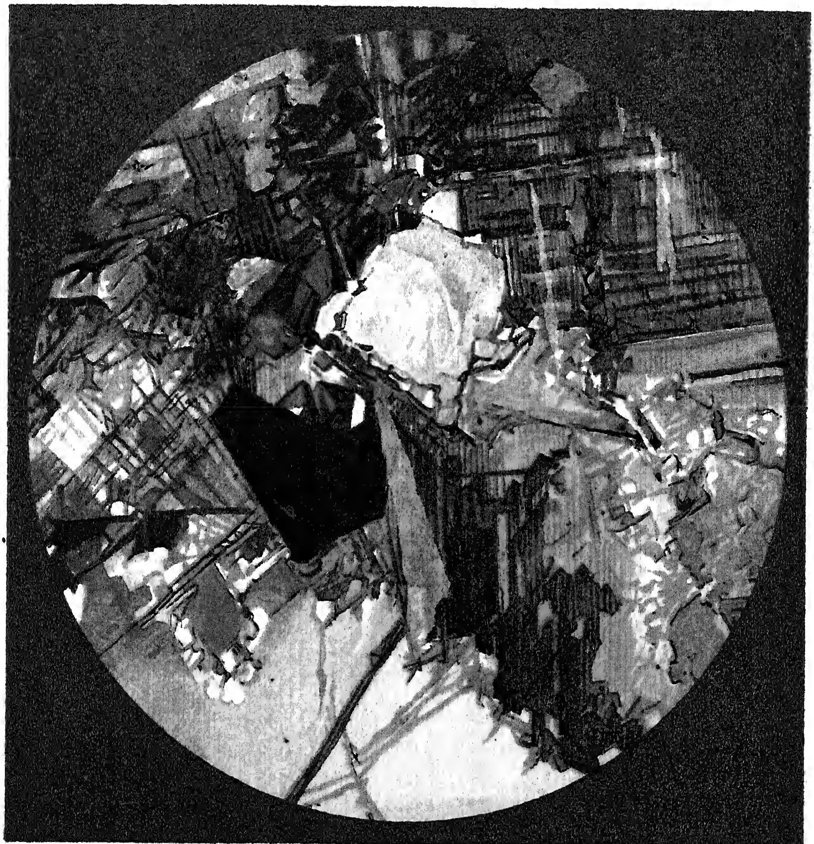


H. Faber, des.

Thin section, in polarized light, of a portion of the Shaft of the Egyptian Obelisk erected in Central Park, New York.

Magnified 35 diameters.

Fig. 2.

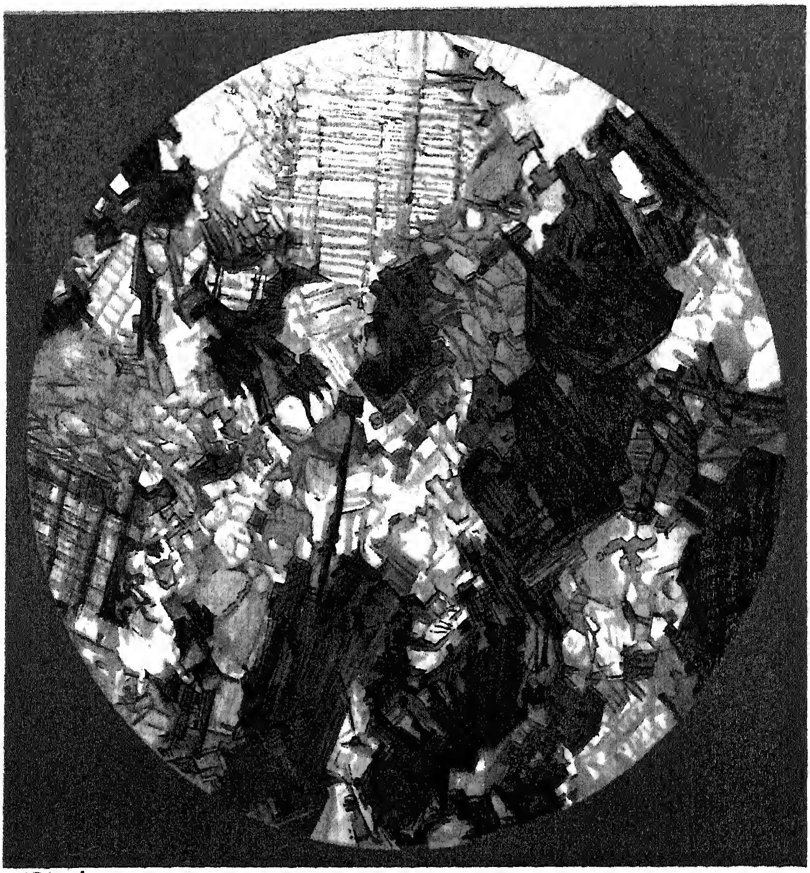


H. Faber, des.

Thin section, in polarized light, of a portion of the Shaft of the Egyptian Obelisk erected in Central Park, New York.

Magnified 35 diameters.

Fig. 3



H. Faber, des.

Thin section, in polarized light, of a Rock near Germantown, Philadelphia, magnified 35 diameters.

Fig. 4

H. Faber, des.

T. Sinclair & Son, Chromo-lith

Fragment of the Shaft of the Egyptian Obelisk in Central Park, New York; natural size and color.

51. *Savary.* Lettres sur l'Egypte. Paris, 1785, in 8vo.

52. *M. Volney.* Voyage en Syr. et Egypte. Paris, 1787, in 8vo.

53. For origins, consult Herodotus, Strabo, Diodorus Siculus; also, Traité complet de Mecan. appliq. aux arts, J. A. Borgois, vol. i, p. 312; and, Dictionnaire des découvertes faits en France, de 1789 à la fin de 1820, vol. xii., p. 258.

54. *P. Badouin.* De l'obélisque de Louqsor. Paris, 1834, in 8vo. [7566.]

55. Extrait du Journal de l'Institute, par Alex. Lenoir.

56. Lettre à M. Champollion sur les hieroglyphes signé. François Salvolini. [7567.]

57. Descrip. de l'obêlisque de Louqsor et l'hist. de son voyage. Paris, 1836. [7574.]

58. Henry H. Gorringe, Lieutenant-Commander, U. S. N. Egyptian Obelisks. Published by the author. New York, 1882.

THE METHOD OF COLLECTING FLUE-DUST AT EMS ON THE LAHN.

BY T. EGLESTON, PH.D., NEW YORK CITY.

THE importance of condensing the gases which escape from furnaces so as to save both the fine particles of ore carried off mechanically and those which are volatilized, has for a long time occupied the serious attention of metallurgists in all parts of the world. It was my good fortune during the last summer to visit the lead and silver works at Ems, near Coblentz on the Rhine, and through the politeness of Mr. Freudenberg, general director of the works, to study in detail their methods of condensation, and to receive from him the important results which have been obtained through a series of experiments lasting over a number of years. I have thought that these results would be of great interest to the members of the Institute and to other metallurgists in the United States, and I have, therefore, with the assistance of Mr. Freudenberg, prepared a careful, detailed description of the construction of the flues, as well as an account of the various experiments which have been made with them, and the conclusions arrived at as the result of these experiments.

It may be said, in general, that the reason why so little attention has been paid in the metallurgical works of the United States to the collection of flue-dust, is that we are not generally aware of the large amount of material carried off by the gases. This is owing partly to the fact that little or no attention is paid to the subject, and also to the fact that the assays, which are almost invariably made in the dry way, show a result so much below the real contents

of the ore that the loss appears smaller than it really is. If assays were always made in the wet way, the result would be quite different, and probably we would have long ago given attention to this subject of flue-dust.

All the experiments that have been made in the direction of saving the materials carried off by the gas may be comprised in two categories,—those in which attempts have been made to collect the dust by means of water, and those in which water has not been used. The condensation of gases by means of water is at best a very rude method. Experience has shown that both solid and gaseous products, even when not under the influence of pressure or of high velocities, may traverse considerable depths of water without change and with almost no condensation. Water condensation has been used in this country to some extent, but its results have always been unsatisfactory, both because the material which is so condensed is very difficult to treat, being collected as a liquid mud, which when dry is in the form of an impalpable powder, and because the water supply in most of the places where the works are situated is very limited; so that at the present time most of the serious experiments that are being made are conducted altogether without water. It becomes at once a matter of the first importance in these experiments to know whether great length or great volume of flue within a given extent, or great surface in a limited volume, is better for this purpose of condensing the gases. The experiments made at Ems are quite conclusive in regard to this question, and show that great surface is the most indispensable requisite.

It will generally be found that three things are required in any method of condensation. The first, and what is generally considered the most important of these, is the settling and complete separation of the fine particles of ore carried off mechanically by the draft. The second, which in all works where the precious metals are treated is much more important, is the condensation of the material which is volatilized or carried off in a gaseous condition. The third is the retaining of all the particles once at rest in the position where they have first fallen, in such a way that they may afterwards be collected without loss of the precious metals or danger to the health of the workmen. To the latter condition but little attention has been paid in this country. I have formerly had occasion to refer to a very ingenious method adopted by the Pennsylvania Lead Works,* for holding the precipitated or condensed material in the

* Trans. Am. Soc. Mechanical Engineers, Vol. i., p. 8.

position where it fell, which, so far as I know, is the only experiment of this kind made in this country. The question of choice between very long flues and very wide chambers seems to be settled definitely, as we shall see by the experiments made in the works at Ems, the conclusion being, in general, that a maximum of surface, without special reference to volume or length, is what is required, and that this maximum of surface can be better gained, so far as the condensation is concerned, and also more economically arrived at as to cost, by the arrangement which is there used.

The experiments made for condensing the materials contained in the gases were commenced in a systematic way in the year 1874, when, with the object of obtaining volume, both systems, that of short wide chambers, and that of long narrow flues, were constructed, in order to ascertain what should be the principle adopted in the future construction of the works. In order to understand the experiments thoroughly, a ground plan of the smelting works, and of the flues, and a profile of the flue from its point of starting in the works to where it finally terminates in the chimney which discharges the gases into the air, are given on Plate I.

The Ems Lead and Silver Works are composed of two separate establishments. The one which is nearest to the famous watering-place is the mechanical preparation or ore-dressing works, which is one of the largest, the most complete, and also one of the best known in Europe, but with which we have nothing to do in this article. The mines, the smelting works, and a small part of the mechanical preparation works are situated about four miles distant in a valley running at right angles to the valley of the Lahn, through which a small stream runs. The mine and part of the crushing and selecting works are situated on the eastern side of this stream; the smelting works are situated on the west bank of the same stream. These latter consist of a series of buildings containing the furnaces and storehouses, built upon a plateau several meters above the stream, at the foot of a high hill which next the works is very steep, but which, after passing Station 22 (Plate I.), rises more gently. Leading away from the works up the hill, are a series of flues of various sizes, the first part of which runs along an old road up to the first chimney at Station 22, and from there goes directly over the hill to the highest chimney at Station 47. The U-shaped part of the flue c, d, e, f, g, h, on which the shaft and roasting furnaces are situated, is joined to the furnaces by means of short flues. The plan shows the

position and arrangement of all of these buildings and flues. The construction details of the flues at different points will be given later.

The main flue is 1700 meters in length; counting all its branches, its total length is 2271.48 meters. The greatest section of the flue is 4.512 square meters. Its total wall surface is 18,060 square meters. Its highest point at Station 47 is 178 meters above the floor of the furnaces. At this highest point it enters a chimney whose section at the bottom is 2.47 meters and at the top 1.80 meters, and whose height is 45 meters, its top being 223 meters above the furnaces. The ventilating flue N, and its chimney L, which were formerly used for ventilating the shaft and cupel furnace house G, and the flue from the roasting stalls, which ends in the chimney at Station 22, have no connection with the main flue. The short and steep flue *a b*, with its arm *c d*, connects the shaft and cupel furnace house, and also some of the roasting furnaces, with the condensing chamber at Station 16. The gases enter on the southerly side, in the compartment I, Fig. 10, Plate II. These gases move towards the northerly side; those in compartment II towards the southerly side. The flue *e f′*, *f g*, *h i*, *K*, connects the other roasting furnaces with the main flue also at Station 16, but follows around an old road going gradually and with an irregular curve up the hill, and empties its gases into the compartment III of the condensing chamber at *i*, Station 16. The gases enter on the northerly side in the compartment III, join those in compartment II, and enter the main flue at Station 15.

In order to make the description of the process quite clear, sections of the flues at different parts of its course have been given, both to show their methods of construction and the means used for obtaining both volume and surface.

Fig. 1, Plate II., is the flue leading from shaft furnace No. 2 to its union with that leading from No. 3, and from the point where the flues of Nos. 2 and 3 join, to the main flue; and also the flue leading from shaft furnace No. 4 to its union with the flue leading from shaft furnace No. 3.

Fig. 2 is the flue leading from shaft furnace No. 3 to the union of the flue with that from shaft furnace No. 2.

Fig. 3 is the flue from shaft furnace No. 1 to the main flue.

Fig. 4 is the flue from shaft furnace No. 5 to the main flue.

Fig. 5 is the flue from the point of union of the shaft furnace flues to the condensing chamber at Station 16.

Fig. 6 is the flue from the six most southerly roasting furnaces to the main flue, and also the flue from the dressed-ore storehouse to the two most northerly double roasting furnaces.

Fig. 7 is the flue from the two most northerly double roasting furnaces to the end of the dressed-ore storehouse; also the flue which runs by the most northerly roasting furnaces.

Fig. 8 is the flue of the most northerly roasting furnaces.

Fig. 9 is the flat flue of the most northerly roasting furnaces.

Fig. 10 is the first condensing chamber on the top of the first incline at Station 16.

Fig. 11 is the flue from the condensing chamber to the outside of the old chimney at Station 22, and from here to the edge of the woods, and from the edge of the woods to the flues connecting with the chimney at Station 47 on the top of the hill; also the flues connecting with the chimney.

Fig. 12 is the condensing chambers X and Y beyond the chimney, but connecting with it.

The flues in the interior of the shaft furnace building are made of sheet-iron plates 1½ millimeters thick, and are hung 30 centimeters above the throat of the furnace. Figs. 1, 2, 3,* show some of the flues which lead from the cupel furnaces. Flues of the same kind are used in the desilverization works, but they belong to their own system of condensation, and do not connect with the main flue. Some slight changes in these dimensions are occasionally made on account of local circumstances, but the size of the larger part of them is one square meter. The lower parts of Figs. 1 and 2 have triangular projections, which have a base of two meters and are one meter high. All these pointed chambers have doors at the end of each incline, so as to make it possible to clean each pocket while the furnaces are in work. In order that the dust may not inconvenience the workmen while the flues are being cleaned, a sheet-iron pipe 40 centimeters in diameter is put underneath them. Into this pipe another one, which is conical at its upper end, fits loosely so that it can be moved up and down. This is put under the triangular pocket, the cone shoved up under it, the door opened, and the dust allowed to fall down into a receptacle made for the purpose, without interfering with the workmen. Iron flues connect with these pocket flues and conduct the gases to the main flue outside the building. By this very ingenious contrivance the dust can be almost automatically removed from the

* The exact location and position of each one of the figures is given in Table I., p. 388.

flues (the cleaning of which would be more or less difficult or dangerous), without stopping the furnace; and a large amount of valuable material is taken at short intervals out of the gases before they pass into the main flue, where it would otherwise be obliged to lie until the end of the campaign.

The flues on the outside of the shaft furnace building are of mason work. They have different sections according to the quantity of gas which they are required to carry off. These are shown on Figs. 4 to 9 and on Fig. 11. It has been found by experience that the arched flues, which at first characterized the whole of the construction, although of an excellent shape for resisting pressure from the outside, do not stand well against internal pressure, and that cracks are made in them so frequently that they are now being abandoned. The flue with rectangular section, Fig. 9, is not subject to these objections, and this style of construction is now adopted in these works and elsewhere in Europe. The roof of this flue is made of old rails covered with brickwork, and is inclined on the outside to one side, so as to shed the water. The cost of construction of this kind of flue is much less than when it is vaulted, and it has a much greater volume for the same height and superficial area, and while it is just as likely to be acted on by the gases it is much more easily repaired. As it is much lower, the dust falling from the top falls from a less height, and is not therefore so likely to be carried any great distance from where it fell. The cross section of the condensing chamber at Station 16 is shown at Fig. 10. The ceiling of this chamber is made out of old rails with cap bricks. Above this is a wooden roof made tight with pasteboard underneath the tiles. In every section of the flue, at convenient distances, man-holes are made for cleaning it out, and to facilitate repairs. These man-holes were formerly about 0.6 meter in diameter, and were made exclusively on the top. It has been found more convenient to make large rectangular openings on the sides which, during the working, are closed with a wall of thin brick, and made tight on the sides and face with mortar. These walls are easily torn down to allow of the men entering on the floor of the flue with wheelbarrows to clean the dust out, and greatly facilitate the repairs to the flues. The earth is now being removed from the sides where the construction makes it possible, for the purpose of making these inlets. This has been found also to reduce the temperature of the flue, a matter of considerable importance so far as repairs to the flue are concerned, for, especially

with the arched flue, when the temperature is either high or very variable the walls have cracked and required constant repairs, which has at times necessitated the stoppage of the works. Every care is taken to carry the drainage of the surface over the top of the flue and not to allow the collection of water at any point. The flues over this whole line are now generally very tight. As the earth which covers or is in contact with them is much warmer than that of the neighboring ground, the grass is much greener than at other points, a sufficient evidence that no large amount of leakage occurs. I walked over the whole length of the flue, examining its construction carefully, and was conscious of the escape of the gases only in one or two points, and that to no very great extent, and principally in the arched portions of it. Repairs to such a flue could not generally be made without shutting down the works. In one of the works in Belgium I saw a very ingenious device for repairing a damaged flue without stopping the works. It consisted of a pipe of sheet iron of the same section as the main flue, washed on the inside with a mixture of silicate of soda and sulphate of baryta. The part of the flue to be repaired was cut out, and this pipe substituted for it, while the permanent flue was being rebuilt. This iron pipe was about one meter in diameter, of thin sheet-iron, and had resisted the hot sulphurous gases perfectly for several months. I carefully examined several sections of it, which showed no trace of oxidation or deterioration of any kind on the inside, and it was pierced only where acid waters had come in contact with the outside. But for this ingenious device the whole works would have had to be shut down for several months.

Up to the year 1877 the chimney shown at Station 22 was the one used for carrying off all the furnace gases. The flue used up to the year 1874 was torn down, as it was too small for the increased production of the works, and was replaced by a larger one, better arranged for taking off the dust. In 1874 a large chamber was built next to this chimney, but after some years it was abandoned on account of the large amount of repairs which were required, and the chamber shown at Station 16 (Plate I.), and Fig. 10 (Plate II.), was then built. It was thought necessary, at the time it was constructed, to make an arrangement by which it could be cleaned very frequently, whenever the works should increase their production, and to have a cut-off, shown at *b* and *k*, so that the gases might be made to pass beside it into the main flue while it was being cleaned. It was

found, however, that the small quantity of dust collected made this unnecessary.

In the year 1877, the chimney at Station 47 (Fig. 13) was built, and connected with the flue leading to it on October 1st of that year. It was found necessary afterwards to increase the condensation surface, and on October 1st, 1880, the two buildings (X and Y, Plate I., and Fig. 12, Plate II.), containing condensing chambers, built beyond the chimney, were added to the flue. These buildings are 100 meters long. Each one of them consists of an upper and a lower chamber, with two divisions in each, separated by a flat ceiling which rests upon iron rails. The roof is inclined at an angle of 35°, and is made of iron rails riveted together with angle iron. Tiles are laid upon this, and the joints covered with clay. The roofing which was put upon the northern section did not stand well, and, in consequence, in the latter part of the summer loam was laid over it, and this was covered with a second coating of beton. As sulphurous acid sometimes escaped from some of the other roofs, they were treated in the same way, and were then painted with tar. This kind of roofing does not appear to last very long, and is liable, on account of cracking, to require considerable repairs. When I visited the works, in September, 1882, the whole of the upper part of the chamber (Fig. 12) had been put out of use, as the roof was leaking gas so badly as to render the works liable to heavy fines. A large amount both of volume and surface was thus lost at that point, but the surface was almost immediately regained by the system described further on. The chimney is shown at Fig. 13. It is 42 meters in height above the socle, and its diameter is 2.47 meters in the lower part, and 1.80 meters above. As it was thought that this chimney might have a stronger draft than the proper working of the furnace would admit of, a movable damper was put in it (Fig. 13). On the outside a quadrant was placed; an arrow attached to the axis moving over the quadrant shows exactly the angle of the damper in the interior of the chimney. When everything is working well, the angle is 45°. Before the addition of the chambers, X and Y, it was as low as 27°. The gas passes out of the main flue at *n*, by an elbow at Station 47, and enters the under part of the southern section of the condensing chamber building X (Fig. 12); it passes from that to the upper part of the same building, and then, at *p*, to the under part of the northerly building, Y, then, at *q*, into the southerly part, and finally, at *r*, by an elbow, *r s*, enters a section of the main

flue, which has been walled off just beyond the elbow *n*, and from there goes directly to the chimney.

A number of experiments have been made to ascertain the temperature of the interior of the flues. It has been uniformly found that the temperature of the gases in the roof of the chambers was as shown in the table below:

At Station 15, ...	136° C.
" " 24, ...	119
" " 35, at *m*, ...	108
At entrance of last chambers, X, Plate I., and Fig. 12, Plate II., .	89
Coming out from the " Y, " "	64

Although the sum of the sections of the two flues *ab*, *gh* is larger than that of the main flue at Station 16, they are not entirely filled with gas, and it is therefore not full, and consequently the temperature on the bottom is always some degrees lower than at the roof. The difference between these two temperatures is greater as the temperature of the gas is higher, and also as the height of the flue is greater. At Station 15, where the shaft-furnace flue joins the main one, it was found to be 8°; at the entrance to the chimney at Station 47, it was found to be 2°. The mean outside temperature varied, during the days upon which these observations were taken, between 6° and 10°.

Table I., below, gives the dimensions, volume, and cost of the different parts of the flue, and the sections into which it has been found desirable to divide it, for keeping the record of the action of the different parts of the flue. The cost has been given in marks. The value of one mark is $0.238.

TABLE I.

NAMES OF THE DIFFERENT FLUES.	No. of the Section.	Description on the Plan.	The section is given on Table II.	Principal Divisions of the Canal. Length.	Width.	Height to the Arch.	Surface of the Side Bottom and Arch. Total.	Per Runni'g Meter.	Cost, not including the Cost of the Ground. For 1 sq. Meter of Inner Surface. M'rks	Pfen-nigs.	For the Running Meter. M'rks	Pfen-nigs.	For the Whole Length. Marks.	Pfen-nigs.
				Mtr.	Mtr.	Mtr.	Sq. Mt.	Sq. Mt.						
1. From shaft furnace No. 3 to union with shaft furnace No. 2.	I.	......	Fig. 1	9.85	1.	1.10	43.72	4.43	11	90	52	82	520	27
2. From shaft furnace No. 2 to union with shaft furnace No. 3.			" 2	5.05	1.	1.50	27.80	5.50	11	90	65	51	330	82
3. From the union of shaft furnace Nos. 2 and 3 to the flue......			" 2	18.	1.	1.50	96.69	5.50	11	90	63	86	1149	54
4. From shaft furnace No. 1 to the flue........................			" 3	8.	0.75	0.75	24.00	3.00	11	90	35	70	285	60
5. From shaft furnace No. 4 to union with shaft furnace No. 3			" 2	14.	1.	1.50	72.00	5.14	11	90	61	20	856	80
6. From shaft furnace No. 5 to the flue........................			" 4	9.	0.60	0.45	18.90	2.10	6	20	13	02	117	18
7. Flue from junction with shaft furnace to the chamber..........	II.	a b	" 5	110.	1.50	1.05	655.05	5.95	17	30	102	93	11332	30
8. Flue from the six southern roasting furnaces to main flue......	III.	d e	" 6	20.	1.20	1.20	109.68	4.28	15	85	67	83	1736	60
9. Flue from the northern double furnaces to end of schlich house........................	III.	e f'	" 7	54.50	1.50	1.50	373.60	6.85	16	46	112	75	6144	87
10. Flue from the dressed-ore storage house up to the two northern double roasting furnaces........................	III.	f' f	" 6	41.	1.20	1.20	224.84	4.28	15	85	67	83	2781	03
11. Flue parallel to the northern roasting furnaces....................	IV.	f g	" 7	66.	1.50	1.50	452.43	6.85	16	46	112	75	7441	50
12. Flue of the northern roasting furnaces....................	IV.	g h	" 8	397.	1.96	0.70	2555.57	6.43	15	78	101	62	40343	14
13. Flatter flues of the northern roasting furnaces....................	IV.	h i	" 9	66.	3.	1.50	594.00	9.00	9	76	87	84	5797	44
14. Chamber on the furnace hill....................	V.	......	" 10	16.30	9.30	4.50 / 3.60	708.00	43.47	10	23	445	00	7253	46
15. Flue from chamber on the furnace hill to the upper part above old chimney....................	VI.	k l	" 11	160.60	1.80	1.80	1321.09	8.22	13	30	109	32	17556	79
16. Flue from above old chimney to edge of woods....................	VII.	l m	" 11	411.30	1.80	1.80	3383.35	8.22	13	30	109	32	41963	31
17. Flue from edge of woods to the close of the chamber..............	VIII.	m n	" 11	375.50	1.80	1.80	3088.86	8.22	13	30	109	32	41019	66
18. End of the flue....................	IX.	n o	....	20.50	1.80	1.20	144.03	7.02	10	44	73	38	1504	29
19. Under southerly chamber (I)....................	IX.	X	" 12	100.	3.00	1.50	933.30	9.00	7	57	68	13	6813	00
20. Upper southerly chamber....................	X.			98.	3.17	2.50	1165.30	11.89	6	73	80	01	7810	98
21. Upper northerly chamber....................	XI.			98.	3.17	2.50	1165.30	11.89	6	73	80	01	7810	98
22. Under northerly chamber....................	XII.			100.	3.00	1.50	933.30	9.00	7	57	68	13	6813	00
23. Connection from 1st to 2d chamber building....................	XII.	p g	....	8.50	3.00	1.50	76.50	9.00	9	76	87	84	746	64
24. Under southerly chamber (II)....................	XIII.	Y	" 12	100.	3.00	1.50	933.30	9.00	7	57	68	13	6813	00
25 Upper southerly chamber....................	XIV.			98.	3.17	2.50	1165.30	11.89	6	73	80	01	7810	00
26 Upper northerly chamber....................	XV.			98.	3.17	2.50	1165.30	11.89	6	73	80	01	7810	98
27. Under northerly chamber....................	XVI.			100.	3.00	1.50	933.30	9.00	7	57	68	13	6813	98
28. Flue from under northerly chamber of No. 2 chamber building to the flue....................	XVII.	r s	....	22.	2.10	1.85	200.13	9.10	18	08	164	52	3619	44
29. The chamber joining the chimney to the northernmost chamber....................	XVII.	s t	" 11	10.38	1.80	1.80	85.37	8.22	16	33	134	23	1394	34
				2635.48			22649.92		11	27	96	81	255150	94

The cost of constructing the flue was large in certain parts of it, on account of the difficulty of carrying the building materials up to the high ground where the flue was built. On comparing the cost of each part of the flue, it appears that the flat portion of Section IV., Fig. 9, as well as the large condensing chamber buildings, X and Y, Fig. 12, were the cheapest. It must be noticed, however, that two of the flues have nothing to do with the saving of the flue-dust. One of these is the one which goes to the old chimney at Station 22, and carries the gases from the stalls used for roasting the lead matte. These stalls are used only a short time during the year. The other is the one used for the ventilation of the shaft-furnace house.

Around each one of the five Pilz furnaces, one meter from its outside, and one and a half meters above the furnace-hearth, a sheet-iron cylinder two millimeters thick is placed. It is open below but closed above, and is joined to a pipe fifty centimeters in diameter. Each one of the pipes for the five furnaces passes through the charging-floor. They meet together outside of the building in a flue, which leads to the chimney L at Station 13, which chimney is 18 meters high and 43.5 meters above the charging-floor. This furnishes sufficient draft to carry off the fumes.

Table II., below, gives the results which have been obtained with the flues just described during seven campaigns. It gives also their length, interior dimensions, and cubical contents during the different periods of construction and change, and also the results which have been obtained by 100 meters in length, 100 square meters, and 100 cubic meters respectively.

TABLE II.

	Length of the Campaign.		The Lead Dust collected compared to 1000 Kilos. of the Lead contained in the Ore.	Flues and Chambers.					The Lead Collected, compared to 1000 Kilos. of the Lead treated in the Roasting Furnace.				
	Date.	Time in Days.		Length.	Section on the Ground.	Side and Arch Section.	Section.	Cubical Contents.	100 Mtr. Length.	100 sq. M Section on the ground.	100 sq. M Side and Arch Section.	100 sq. M Section.	100 cub. Meters. Cubical Contents.
			Kilos.	Meter.	Sq. Mtr.	Sq. Mtr.	Sq. Mtr.	Cub. Mtr.	Kilos.	Kilos.	Kilos.	Kilos.	Kilos.
1	May 1, '74, to Dec. '75, . . .	579	8.39	462.00	577.30	1808.17	2385.47	829.76	1.8160	1.4350	0.4640	0.3517	1.011
2	Jan. 1, '76, to April 15, '78, .	470	14.66	723.00	909.25	3238.62	4147.87	1565.86	2.0280	1.6120	0.4530	0.3534	0.9362
3	May 1, '77, to April 15, '78, .	350	26.71	1123.15	1685.07	6221.00	7906.06	3599.55	2.3780	1.5850	0.4290	0.3353	0.7420
4	May 1, '78, to May 21, '79, .	386	34.30	1308.47	2229.00	8481.68	10710.68	5336.93	2.6210	1.5390	0.4050	0.3202	0.6427
5	June 3, '79, to Dec. 3, '79 = 203 Jan. 1, '80, to Sep. 13, '80 = 257	460	42.56	1308.47	2229.00	8481.68	10710.68	5336.93	3.2530	1.9090	0.5020	0.3973	0.7975
6	Oct. 1, '80, to Aug. 11, '81, . .	314	80.01	2635.48	5881.55	16769.07	22650.62	11025.59	3.0359	1.3604	0.4771	0.3532	0.7257
7	Aug. 28, '81, to Mar. 24, '82, .	200	84.80	2635.48	5881.55	16769.07	23791.14	11025.59	3.2176	1.4417	0.4734	0.3564	0.7691
8	April 16, '82, to Sept. 23, '82, .	160	. . .	. . . . . .	. . . .	. . . . . .	34241.98	. . . . .	. . .	. . .	. . .	. . .	. . . . .

In making the comparison of the material collected on every 100 square meters of wall surface and that in every 100 cubic meters of contents, the first four campaigns are particularly noticeable, as in these the relation of the square meter to the cubic meter, that is, to the mean section of the flue, has frequently changed. When the flues were first built, they were made, as they usually are elsewhere, narrow. Those more recently constructed, which have served partly to replace defective ones and partly for the increased production of the works, are made much larger than they formerly were. The mean section of the entire flue has in this way become constantly larger, so that when the old flues were finally destroyed the large section was taken as the normal one for the new ones. In the first campaign the section of the flue was 1.79 square meters; in the second, 2.16 square meters; in the third, 3.21; and in the fourth, fifth, and sixth, 4.08 each. The only change in the seventh campaign was the insertion of 23,791.12 square meters of sheet-iron plates. Very little data can be given with certainty for the eighth campaign; several accidents occurred, which made it necessary to make the gases exit at the chimney at Station 22, so that for some time a large part of the flue was not in use. The cleaning and transportation of the flue-dust was made in very rainy weather, which made the weight of it uncertain. For these reasons this campaign has been left out of the question. Making a comparison of the quantity of lead collected per square meter of wall surface in the first four campaigns, the table shows that the quantities were nearly alike and varied regularly in very small quantities, while, on the contrary, the quantity collected per cubic meter during the enlargement of the flue was considerably less. From this the conclusion may be drawn that the material collected under such circumstances is proportional to the extent of wall surface, and that the cubical contents of the flue, including the chambers, has very little influence when the quantity of wall surface has undergone any change. These conclusions are fully sustained by the experiments formerly made with the two large condensing chambers X and Y, the increase of the cubical contents of the flue, owing to their addition, having been almost without influence.

The amount of dust collected on the bottom of the flue and of the condensing chambers was always much higher on the sides than in the middle, owing to the fact that after a certain quantity is caught on the walls, it falls to the bottom of the flue from its own weight and is heaped up there. In the last two campaigns a very much more favor-

able result was obtained than in the four previous ones, owing to the fact that much greater attention was paid to the regulation of the draft by the damper in the chimney, which was so far closed that the furnaces had only the necessary draft. The material contained in the gases had thus much more time to settle on the sides, and that which had already settled either there or on the roof was not unnecessarily detached from it. The proportional quantity of dust collected upon a square meter of wall surface under similar circumstances is necessarily smaller the greater the section of the flue, so that by increasing the wall surface from 10,710 square meters as in the fifth campaign to 22,650 square meters as in the sixth, to 23,791.14 square meters as in the seventh, and to 34,291.98 square meters as in the eighth campaign, the decrease of the material collected per square meter of surface is easily understood. The conclusion was therefore drawn, after the results of each period were known, that the wall surface of the flue might safely be enlarged, which was accordingly done. Before discussing the best way to make the final enlargement of the flue, it is well to discuss carefully the results obtained in the collection of the dust in the latest campaigns. From October 1st, 1880, to August 11th, 1881, which comprised the sixth campaign of the works, 14,605,261 kilograms of lead ore containing 6,247,605 kilograms of lead were treated in the works.* During this time, 927,483 kilograms of dust were collected, which contained 499,875 kilograms of lead. Per 1000 kilograms of lead contained in the ores treated, the dust contained $\frac{499{,}875 \times 1000}{6{,}247{,}605} = 80.01$ kilograms. The manner in which this dust settled in the whole flue system is shown in the table below.

* All the determinations of lead which are given in this article have been made in the wet way.

TABLE III.

Sixth Campaign, lasting from Oct. 1, 1880, *to Aug.* 11, 1881.

In Section.		Dust.			Quantity of Lead per 100 Square Meters of Wall Surface.
No. of Section.	Square Meter of Ground, Side Wall, and Arch Surface.	Weight.	Lead contained.		
	Square Meters.	Kilos.	Per 1000 Kilos.	Total Lead. Kilos.	Kilos.
I.	283.02	68699	340.70	23405.97	8270.08
II.	655.05	43102	604.13	26039.34	3975.23
III.	708.12	53939	393.80	21241.56	2999.71
IV.	3602.00	92225	479.90	44285.78	1229.48
V.	708.70	71187	606.50	43174.92	6092.13
VI.	1321.09	65154	612.70	39919.85	3021.74
VII.	3383.35	157874	608.50	96066.33	2839.38
VIII.	3088.86	130950	556.70	72899.86	2360.09
IX.	1077.33	27319	610.20	16670.05	1547.35
X.	1165.30	39658	593.40	23533.06	2019.49
XI.	1165.30	32738	592.70	19403.81	1665.13
XII.	1009.80	26922	512.20	13789.45	1365.56
XIII.	933.30	19599	579.60	11359.58	1217.14
XIV.	1165.30	32405	507.80	16455.26	1412.10
XV.	1165.30	28688	473.60	13586.64	1165.93
XVI.	933.30	23713	467.10	11086.34	1187.86
XVII.	285.50	13311	524.70	6984.28	2446.33
	22650.62	927483	538.96	499902.08	2206.89

The great decrease of the lead in the dust is very noticeable. It is caused by the fact that before cleaning the flue the dust is usually set on fire. This is done in several sections at the same time, and is easily started with a single match. It is usually done with a handful of lighted shavings. It is burned to get rid of the soot, the very fine coal, and a part of the sulphur contained in the dust, so that the flues can be cleaned with less difficulty and danger to the workmen, and to change the very light dusty material into a compact agglomerated mass, which can easily be treated in the shaft furnace. This method of burning is successful if the dust has accumulated to a considerable thickness, when, as the coke and sulphur are burned out, the residue contains the most lead. That which is in thick layers, as it is generally the best burned, contains the highest percentage of lead. Whether the layer is thick or not is, however, for the purposes of this paper, a matter of no consequence, as all that it is necessary to know is, how much lead is collected per square meter of wall surface. The table below gives

the different sections into which it has been found convenient to divide the flue for more easy reference.

Designation of the Different Parts of the Flue.

No. of Section.	
I.	Sheet-iron flue in the shaft-furnace house.
II.	*a b*. Flue from shaft and roasting furnaces to Station 15.
III.	*c d* and *e f*. Flue for the three roasting-furnace houses.
IV.	*f g*, *g h*, and *h i*. Flue from the last roasting house to chamber V.
V.	Condensing chamber.
VI.	*k l*. Flue from the condensing chamber to the old chimney.
VII.	*l m*. Flue from the old chimney to the woods.
VIII.	*m n*. Flue from the woods to the chamber-house.
IX.	*n o*, and lower southern division of chamber-house.
X.	Upper southern " "
XI.	Upper northern " "
XII.	Lower northern " "
XIII.	*p q*, and lower southern " "
XIV.	Upper southern " "
XV.	Upper northern " "
XVI.	Lower northern " "
XVII.	*r s* and *s t*.

The first section comprises the sheet-iron flues in the shaft-furnace house through which the shaft-furnace gases are drawn off. The second section is, for the most part, subterranean, and comprises that part of the flue which goes from the furnace in the buildings G (Plate I.), and the three southerly roasting furnaces in the building I, towards the chamber *k*, between Stations 15 and 16. The gases from the shaft furnace and from the three most southerly roasting furnaces are carried off by it. The third section comprises the mostly subterranean flue, *c d*, and *e f*, the southerly part of which enters the flue *a b*, and the northerly part of which, Sec. IV., *f g*, *g h*, and *h i*, takes the gases from the roasting furnaces in the adjacent buildings, and comprises all the other stations of the flue up to Station 16. At Section V., which is the large chamber, the gases are mixed at Station 15 with those coming from the rest of the furnaces. Table III. shows the very large quantity of lead per square meter of wall surface which was collected in Sections I. to V. In Section I. the quantity is more than twice as large as in its continuation in Section II., notwithstanding that here the gases from three roasting furnaces are collected. It was to be expected that more would be collected in Section I. than in Section II., as the dust mechanically carried off is an important factor in the beginning of the

flues, but that the difference should be so very great must have another cause. As the gases from Section II. and those coming from Section IV. come together in the chamber of Section V., it was to be expected that more dust would collect there. The amount collected, however, should, when the conditions remain the same, be less than the sum of that collected in Sections II. and IV. According to the table, however, it is considerably larger. It is possible that this, as well as the unexpected quantity collected in Section I., is due to the fact that the walls in these two sections are entirely above ground, and are therefore easily cooled, while those of Sections II., III., and IV. are, for the most part, buried in the earth, and will, therefore, sooner or later acquire a temperature near to that of the gas. Apart from the condensing surfaces, the difference between the temperature of the gases and that of the walls of the flue should make a difference in the quantity of gaseous metals which can be condensed. The height of the temperature of the gases themselves has probably little or nothing to do with it. This, at least, seems to be the undoubted conclusion to be drawn from the results obtained in the Sections II. to XVI. When the different sections of the chambers are compared, as in Figs. 14 and 15, the greater quantity of material collected per hundred square meters of wall surface in the upper than in the under part strikes the eye at once. This can only be explained by the fact that the gases are more thoroughly cooled in the upper than in the lower part, the difference between the upper and the lower sections being that, with the exception of the partition floor, which is common to both, the side walls of the under part are made of thick masonry and are buried in the earth, while the upper one has very thin walls which are free.

Another argument to prove that cooling has an influence over the quantity precipitated is shown in the more rapid diminution in the upper section than in the lower. While the amount precipitated in the upper compartment varies from 2019 to 1165 kilos., that in the lower varies only from 1547 to 1187. This is undoubtedly caused by the fact that the gases in Section X. were at a temperature of 89° C., while those in Section XV. were at 64°. The difference between the highest and the lowest temperature in Section X. was, therefore, considerably greater than in Section XV., as was also the reduction of their individual temperatures. The reason that the precipitation per 100 square meters of surface in Section IX. is less by about 813 kilos. of lead than in the previous section, while the

precipitation in Section VIII. was only about 479 kilos. of lead less than in the one previous to it, is explained by the fact that Section VIII. lies with one side and the roof free to the air, and Section IX. is entirely buried. The calculation of how much has been collected per 100 square meters in Section XVII. is uncertain, because the dust found in the bottom of the chimney was weighed with it, and there is no means of ascertaining how far the quantity collected there was affected by the inner surface of the walls of the chimney.

Up to this time reference has only been made to the lead contained in the dust. The other components, however, are of interest, especially the silver, as its amount is always of some importance. The last time the flue was cleaned, the dust, according to an assay of 1000 kilos., contained 51.86 grams of silver, so that the total amount of silver contained in the dust was 48 kilos. If, however, the quantity of silver which is contained in the lead obtained from the roasted and smelted dust is taken as a starting-point, the silver contained in 1000 kilos. would be 72.11 grams, or, altogether, 67 kilos., which quantity is, therefore, the normal from which all calculations must be made. With regard to the repartition of the silver in each section it is the greatest nearest the furnace, and then diminishes, at first rapidly, but after that very slowly. In the last campaign the amount of silver contained in the dust, according to an assay of 1000 kilos., was:

At Station	I.	150 grams.
"	II.	50 "
"	III. Just behind the roasting-furnaces, . .	75 "
"	IV.	60 "
"	V.	45 "

From this point the silver diminishes gradually till at the end of the flue it is only 30 grams.

It appears very clear from these assays that in the beginning the dust contains a considerable quantity of particles mechanically carried off, which, on account of their weight, can only be transported a certain distance. When the draft is stronger they will be carried further, and its influence will be shown in the increase of these small particles of ore. This explains why it is that in former years, when there was no damper in the chimney, there was nearly half as much more silver in the flue-dust as now. From the fact that the ratio of lead to silver in the flue-dust is different from that in the ore, it is certain that in the discussion of this whole question the condensation of the volatilized material is by far the most essential consideration.

The dust contains between three and five per cent. of zinc. In general it can be said that it is greater in the beginning than at the end of the flue. The difference, however, is not very great. The antimony contained is between 0.21 per cent. and 0.40 per cent. It decreases very gradually in the length of the flue. The dust which is deposited on the bottom of the flue often contains 10 per cent. more lead than that which is deposited on the arch. This observation has been confirmed every time the flue has been cleaned. The analyses of two samples of dust which was deposited by Station 46, more than 1500 meters from the beginning of the flue, is given below:

ANALYSES.

	I. Per cent.	II. Per cent.
Lead,	60.48	67.04
Zinc,	3.17	4.22
Silver,	0.003	0.003
Sulphuric acid,	14 78	14.07
Sulphur,	6.22	5.42
Oxide of iron, Alumina,	2.12	1.00
Carbon,	8.00	5.80
Antimony,	0.42	0.31
Arsenic,	0.24	0.16
Copper,	trace.	trace.
Lime,	1.15	0.61
Total,	96.583	98.633

Assay No. I. was taken from the arch, and No. II. from the floor directly under it. The difference between these two will not be apparent when large masses are considered, for the dust increases in depth on the floor, because that which collects on the roof after a time gets heavy and falls to the ground on the top of that collected there, so that the results obtained by the analysis of a sample taken from a large quantity will be a mean of the two, and will not represent either the one or the other.

From these facts it is plain that the most important consideration is not that of collecting the particles of ore which are mechanically carried off, but of condensing and collecting those which have been volatilized and sublimed. Two separate means can be used for condensation, and these are the proper application of wall surface, and some method of cooling that surface. There is a limit to the possible cooling of the wall surface, and in any case this method can only be useful up to the point where the gases are reduced approxi-

matively to the temperature of the outer air; beyond this point artificial means of producing the draft would have to be used. How far the flue can be cooled will depend on the material used for the construction of the walls, and whether the flue itself is more or less buried in the ground.

The limit of methods of construction lies between sheet-iron flues suspended in the air or laid on the surface of the ground, and masonry flues buried entirely in the earth. The lowest point to which the gases can be cooled will be that which will give the necessary draft for the proper conduct of the furnace. The chimney must, therefore, be built either upon a high elevation or must itself be sufficiently high to produce the draft, or the gases at the foot of the chimney must have their velocity increased, either by bringing the gases at that point up to the requisite temperature, or by causing the air to move by power. In the works at Ems little can be gained by the further cooling of the gases, as these at the foot of the chimney at Station 47 on the top of the hill have only a temperature of 64° C., so that to increase the quantity of dust collected more surface must be provided. Since the intercalation of the last two chambers, which with their necessary additions have a surface of 8815 square meters, it has been found necessary to open the damper of the chimney to 45°. Formerly it could only be opened with safety to 27°. There is little or nothing to be done further to increase the draft except to open the damper entirely, or to increase the height of the chimney. This must be done when a second condensing-chamber building, like those at X and Y, is constructed, as it must be. The cost of this construction would be 64,486.29 marks; according to the last experiments that were made, this sum would be repaid at the latest inside of three years. As, however, all that is necessary now is to increase the wall surface, this can be done more quickly and cheaply by placing sheet-iron plates in the flues already constructed. This system was tried in Section XVI. from August 28th to December 24th, 1881. Four rows of sheet iron, No. 22, 100 meters long and one wide, were hung in the flue. Taken together they represented 800 square meters surface; the collective wall surface of this divison was, therefore, increased from 933 to 1733 square meters. The quantity of lead contained in the ore and in the dust at this time was 3,028,565 kilograms. In the previous campaign, of the 6,748,816 kilograms of lead in the ore and dust which was treated, there were collected in Section XVI. 23,713 kilograms of dust. It was, therefore, calculated that with the increased wall surface

from this arrangement of thin plates, 19,766 kilos. would be collected in this. The amount actually collected was 18,800 kilos., which was somewhat higher in lead than that collected in the previous experiment. The results of these experiments were so satisfactory that the number of plates was increased to six, as shown in Fig. 16. The quantity thus collected was so very large that in some of the sections of the main flue, notably in Figs. 11, 12, and 17, vertical plates 10 millimeters apart were introduced. As this method of construction costs only about one-tenth as much as the same amount of wall surface made with masonry, and allows of regaining more flue-dust than the construction of long flues and condensing chambers without it, a patent for the improvement has been taken out in the name of the Ems Lead and Silver Works.* It has proved useful not only for metallurgical but also for chemical and other manufacturing works where metals are likely to be volatilized. It is also probable that its use will be found advantageous in the manufacture of zinc white, the treatment of ores of mercury and other volatile substances, where the main object of the treatment is the condensation of the volatilized metals.

After the first trial the hanging plates were introduced into Sections VI., VII., and VIII., a section of which is shown at Fig. 11. They were then introduced on a much larger scale in Sections V., VI., VII., VIII., and IX., as shown in Figs. 16 and 17.

The method of hanging-in the sheet-iron consists in placing a rectangular bar of iron, which has been pierced with the requisite number of holes, on its edge, in the spring of the arch, if the arched form of flue is used, or at the proper height in the rectangular ones. This bar is twisted flat at its ends so as to enter the wall about 3 cm. Iron pins, 10 cm. between centres, are driven into the holes, projecting 3 to 4 cm. on both sides. A piece of iron, D, Fig. 17, bent to form a hook, is riveted upon the ends of each sheet, so that it simply drops on to the pins, and hangs at each end supported in a vertical position. So arranged, the sheets can be put up or taken down with the least possible trouble. To simplify the construction, a punching machine is used which pierces two holes at once in the sheet-iron at the proper distance from the edge. The iron which forms the hook L, Fig. 17, is punched in the same way. The riveting is done with two or three blows of the hammer. When the sheets are

* Jan. 13th, 1881, Germany, No. 17,513.—March 12th, 1882, Hungary, No. 8454. —October 20th, 1881, England, No. 4590.—April 3d, 1882, Spain, No. 2232.—March 12th, 1882, Austria, No. 3723.—April 24, 1883, United States, No. 276,386.

hung upon the pins they fill up the flue, and have between them in the direction of the length of the flue only the thickness of the iron bars on which they rest. These sheets do not make any perceptible reduction of the total volume of the flue, but they increase the condensation-surface enormously.

Fig. 16 shows the arrangement of Fig. 11 when only six sheets were used; Fig. 17, the arrangement of the same flue when seventeen are used. A vacant space is left, as C E C L in Fig. 17, to show the method of hanging-in the sheets on the iron bars L, as well as the method of supporting the partitions on the bottom of the flue. In order not to impede the draft these plates must be placed parallel to its direction, and be as thin as possible. It will also be necessary to place them as nearly vertical as possible so that when the dust condenses upon them, after it has attained a certain thickness, it will fall down upon the floor of the flue and remain there. In order to bring the quantity of dust which settles up to a maximum, the material which has once been condensed and brought to rest, should remain, as far as possible, where it was arrested, or if allowed to move should fall vertically on to the floor, and remain there, so that it would no longer be possible for it to be caught up again by the draft and be carried up the chimney. The simplest and cheapest means of effecting this, is to make partitions, about 50 cm. high and nearly touching the vertical sheets, across the bottom of the flue, as is shown at E, Figs. 16 and 17. Every five or six meters, or less, partitions are made at right angles to the direction of the draught. In the first experiments they were made of stone, laid up dry, as shown at E, Fig. 16. It has been found best, in the more recent constructions, to make them of sheet-iron, as is shown at E, Fig. 17. The sheet-iron is supported in wrought or cast-iron feet C, to which it is attached by bolts. It is easily set one side when the flue is cleaned, or can be quickly removed from the supports if it is for any reason necessary to do so. This kind of construction has the advantage of not only being easily removed and replaced, and of being quickly repaired, but it is never in the way. The dust collected is purer, because there is no chance of having small particles of broken stone mixed with it. This method of using plates for increasing the condensing surface costs very little, as any kind of sheet-iron can be used. The cost of putting in is only 21 pfennigs. By the ordinary construction one meter of the length of the flue gives only 8.22 square meters of surface; altered in this way, the same length gives, with six plates, 65 square meters of surface, and with

seventeen, 184 square meters, while its volume is lessened only a very little.

In all parts of the flue where these sheet-iron plates have been placed, enormous quantities of dust have been found every time the flue has been cleaned, the quantity being greater as the surface was larger. As no such quantities have been found before, and as the increase in quantity is directly in the ratio of the increase of the surface, there is every reason to believe that it will prove effectual to a higher limit than has yet been ascertained. The quantity of dust collected, especially in the last section of the flue, was very large. Usually, but very small quantities can with certainty be counted on in that position. It seems probable that by the use of a suitable construction, a still larger part of the dust can be collected, and most of that which is now lost saved, thus diminishing the expenses and increasing the receipts of the works very considerably.

With regard to the number of sheets to be introduced in each section of the flue to produce a maximum effect, it may be said the more the better, provided they do not interfere with the draft. It has been found best to use very thin sheets, and to concentrate them, as far as possible, in a small portion of the flue, rather than to scatter them throughout it, or over a very large part of it, as the cost of construction will for this reason be less. Whether more than seventeen or eighteen sheets can be used in a flue of the size of Sections VI., VII., VIII., and XVII., or whether, in a larger flue, it will ever be found advantageous to hang them closer than 0.01 meter apart remains to be seen. Up to the end of the ninth campaign they were hung 0.01 m. apart. So much dust was then collected in Section VI. by this method that the flues became choked and the furnace had to go out of blast. The plates must not be hung too close together at the end of the flue or they will endanger the length of the campaign, unless auxiliary flues are provided, as has been suggested, so that the sections may be cleaned whenever desirable by turning the gases into the auxiliary flue, and when that is full, back again, without stopping the works. No general rule can be given either for the number of plates nor for their relation to the width of the flue, for the quantity of gases passing through it, or the quantity of sublimed material likely to be contained in the gases. They not only differ in the different works, but they are often different in individual parts of the same works. The use of sheets thinner than 0.675 mm. would give more surface for the same volume, but they would have to be supported differently, as they would be likely to be moved

from side to side by the blast. If they were hung from the top, there would be danger of their meeting at the bottom, and thus obstructing the draft. To support them in more than one place would naturally increase the difficulty of using them as well as increase the cost. The introduction of three or four more in the same space would largely increase the surface, but it could not be done advantageously if it increased at the same time the difficulty of manipulation or the cost. More plates would then have to be used in the length of the flue. The cause of failure, if any, in the system would be the increase of friction-surface, and this limit will have to be found in every case. Whether it will be wise to increase the section of the flue in order to introduce more plates can only be ascertained by experiment. When careful records of the action of each shape of flue, where the plates are used, have been made, the ledger account will soon show which form of flue it is most economical to adopt.

The material used for the plates may be different according to the temperature which obtains in that part of the flue where they are to be used. Thin sheet iron seems to be the best, which need not even be new. The worn-out iron sieves of the jigs from the dressing-works can be used, and where the temperature is very low, as in the last section of the flue, next the chimney, on the hill, pasteboard can be used. Combustible material cannot, of course, be used where the flue is to be fired. It would be well to make experiments in each case as to what material is most suitable.

Whether these plates can be best hung up or fixed permanently, must be determined in each special case, as must also the best way of carrying out the rest of the system. It will generally be found best to have them easily removable, to facilitate the firing of the dust (which is peculiar to the works at Ems), as well as to facilitate the cleaning of the flue.

In England a patent was taken out in the year 1880 for plates which are put in horizontally. The object of this invention is to collect the dust by making the draft as slow as possible and causing the particles arrested to fall the shortest possible distance. To diminish the velocity of the gas, it is passed from the main flue into very large condensing chambers, built at the side of the main flue and divided by parallel walls into a large number of flues, in which iron plates are placed horizontally and close together the whole width of the flue, so as to make the fall of each particle as small as possible. There is no doubt that so far as the collection of the dust is

concerned, this system will do it rapidly, but the system itself is both defective and expensive. As the dust is accumulated in horizontal layers, the volume of the flue is rapidly diminished, and as there is no provision made for arresting the dust where it falls, the amount of surface must always be a maximum. It will take a long time for such large condensing chambers to cool down so that the men can enter them, so that much time will be lost before they can be cleaned. The danger to the men by bringing them in contact with this impalpable dust, which is set in motion every time one of these layers is removed, while cleaning the flue, will effectually prevent the general introduction of this method.

The seventh campaign lasted 200 days, the details of which are given in Table IV below.

TABLE IV.

Seventh Campaign, lasting from Aug. 28th, 1881, *to March 24th,* 1882.

In Section.		Dust.			Quantity of Lead per 100 Square Meters of Wall Surface.
No. of Section.	Square Meter of Ground, Side Wall, and Arch Surface.	Weight.	Lead Contained.		
	Square Meters.	Kilos.	Per 1000 Kilos.	Total Lead. Kilos.	Kilos.
I.	283.02	75449	401.163	30267.38	10694.43
II.	655.05	8471	609.300	5161.38	787.93
III.	708.12	12392	433.552	5335.40	743.46
IV.	3602.00	75265	443.316	33336.22	926.32
V.	1049.20	30171	619.047	18677.26	1780.14
VI.	1321.09	35257	628.199	22148.41	1676.52
VII.	3383.35	110576	626.400	69464.81	2047.22
VIII.	3088.86	74050	624.000	46207.20	1495.93
IX.	1077.33	27150	669.106	18166.22	1686.23
X.	1165.30	25150	646.300	16254.44	1394.87
XI.	1165.30	24600	638.300	15702.18	1347.48
XII.	1009.80	22500	615.330	13844.92	1371.05
XIII.	933.30	21950	623.396	13683.54	1466.15
XIV.	1165.30	20950	547.900	11478.50	985.02
XV.	1165.30	26800	577.600	15479.68	1328.38
XVI.	1733.30	33100	595.979	19726.91	1138.11
XVII.	285.50	8900	590.907	5259.07	1842.06
	23791.12	632731	568.999	360193.52	1513.27

The value of the 632,731 kilos. of dust is 88,542 marks. If the seventh campaign had lasted 350 instead of 200 days, the corresponding quantity would have been 1,107,296 kilos. of dust, worth 155,019 marks.

The sixth campaign lasted 314 days. During this time the ore treated contained 6,247,605 kilos. of lead, the details of which are given in Table III. The seventh campaign lasted only 200 days, and the ore treated contained 4,245,303.21 kilos. of lead. In order to make the comparison between the two, the amounts given for the seventh campaign will have to be increased in the ratio of 4,245,-303.21 : 6,247,605. This has been done in Table V., below:

TABLE V.

The Seventh Campaign increased for the purpose of comparison with the Sixth Campaign.

In Section.		Dust.			Quantity of Lead per 100 Square Meters of Wall Surface.
No. of Section.	Square Meter of Ground, Side Wall, and Arch Surface.	Weight.	Lead Contained.		
	Square Meters.	Kilos.	Per 1000 Kilos.	Total Lead. Kilos.	Kilos.
I.	283.02	111030.75	401.163	44541.43	15737.92
II.	655.05	12465.92	609.300	7595.48	1159.52
III.	708.12	18236.06	433.552	7906.28	1094.04
IV.	3602.00	110759.97	443.316	49101.67	1363.17
V.	1049.20	44399.64	619.047	27485.46	2619.65
VI.	1321.09	51884.20	628.199	32593.60	2467.17
VII.	3383.35	162723.64	626.400	101930.09	3012.69
VIII.	3088.86	108971.98	624.000	67998.52	2201.41
IX.	1077.33	39953.94	669.106	26733.42	2481.46
X.	1165.30	37010.74	646.300	23920.04	2052.69
XI.	1165.30	36201.36	638.300	23107.33	1982.95
XII.	1009.80	33111.00	615.330	20374.19	2017.64
XIII.	933.30	32301.62	623.396	20136.70	2157.59
XIV.	1165.30	30830.02	547.900	16891.77	1449.56
XV.	1165.30	39438.88	577.600	22779.90	1954.84
XVI.	1733.30	48709.96	595.979	29030.11	1674.84
XVII.	285.50	13097.24	590.907	7739.25	2710.78
	23791.12	931126.92	568.999	529865.24	2226.93

It is to be noticed that in Section V., which is the condensing chamber at Station 15, shown at Fig. 10, the quantity of wall surface has been increased from 708.10 square meters to 1049.20 square meters, and that of Section XVI., which is the lower northerly part of the condensing chamber Y, at the top of the hill, Fig. 12, from 933.30 to 1733.30 square meters. Section V. is very near the furnaces. Section XVI. is at the foot of the chimney.

Table V. shows that there has been a very large increase in the

quantity of dust collected, except in Sections V., VI., VIII., X., and XIV., where the quantities are in round numbers 26,000, 13,000, 3000, 2500 kilos. less. The total quantity collected is, however, greater than in the sixth campaign, and almost in direct proportion to the increase of wall surface. But in every case where there is a diminution, except in Section XIV., there is an increase in the quantity of lead per 1000 kilograms. The quantity of lead per square meter of wall surface is less in Sections V., VI., and VIII., and slightly more in Sections X. and XIV. The total quantity is, however, enough more to justify close attention.

It would naturally have been thought best, as soon as the practicability of this method of using iron plates had been proved, to have hung the whole flue full of them, but as no sufficient data had been collected as to how far the draft would be affected by it, it was done very gradually. Before the seventh campaign, in August, 1881, 1140 square meters were put in. In March, 1882, before the eighth campaign, 10,450.86; and after the eighth campaign, in September, 1882, 13,055.35 more, so that up to this time there were 24,471.60 square meters of sheet-iron plates hung in the flue. An accident, which happened in the summer of 1882, made it necessary to do away with the upper part of the condensing-chamber building, which includes Sections X., XI., XIV., and XV., Figs. 14 and 15, as the roof was no longer tight. The flue itself had then 18,060.01 square meters of wall surface; this, with the 24,471.60 square meters of sheets, made 42,531.61 square meters of available condensing surface. The sheet-iron plates introduced cost 18,108.98 marks. If this amount of surface had been introduced by means of a masonry canal, such as is shown in Fig. 9, the square meter of which costs at least 11.71 marks, it would have amounted to 286,562.44 marks. There was thus saved by the use of the iron plates a sum of 268,453.46 marks.

It was a matter of some interest to ascertain whether the draft had not been diminished by the enormous friction surface which had been added in the flue, by the very large amount of surface introduced into it. As the entire flue, during the three weeks that the works were obliged to stop for these repairs, was very much cooled, it was found that at the time the works were put into blast again, there was such a very weak draft that it was necessary to put a fire at the bottom of the chimney on the top of the hill. After three days' use of it the draft was sufficiently strong to make it no longer necessary. The damper in the chimney is now not entirely open. Little by little it will be brought back to its former angle.

With regard to the temperature in the flues, the gases escaping from the chimney in the normal working of the establishment have a temperature of between 60° and 70°. With regard to the quantity of lead contained in the dust, setting it on fire undoubtedly diminishes the quantity more or less, but that upon the arch, which afterwards falls to the ground, does not contain as much as that which collects on the bottom. Taking the sample for the assay is on this account very difficult, and mistakes are very apt to be made, when the fact of the dust collecting in layers of variable richness is not taken into account. The assays taken at the end of the seventh campaign were in any case more nearly correct than those taken at the end of the sixth.

The sheet-iron plates which have been hung have lasted extremely well. Not one of them has as yet been damaged, and it seems more than likely that they will last at least five years. The only danger appears to be from dampness which would cause them to rust, and this can only be avoided by confining the places in the flue where they are hung to such a distance from the furnaces that it is certain that all the dampness will have previously been condensed out of the gases, and by properly draining the surface so that no moisture can collect in the flue from the outside. By this system it is possible to collect the whole of the dust in a small part of the flue near the works, and thus save a large amount of transportation of the material collected, while at the same time diminishing by so much the loss consequent on carrying it. This loss by transportation will, of course, be reduced to a minimum when the dust is agglomerated.

Cleaning the flue necessitates, at certain intervals, a stoppage of the works, so that only those places are frequently cleaned in which the sheet-iron hangs, while the flue itself is cleaned at longer intervals. In those places where a stoppage of the works is impossible, two flues filled with sheet-iron plates can be built side by side in the most convenient situation, so that either one may be connected with or cut off entirely from the main flue, according as they have been cleaned or are to be cleaned, without stopping or even hindering the work of the furnace at all.

In order to ascertain how far this system of enlargement of the flues can be carried without danger, and how far the wall surface can be increased, and what is the limit at which it would pay, a table of the results of the sixth and seventh campaigns at Ems is given below in Tables VI. and VII., taking as a basis Table III., page 393.

The sixth campaign was 314 days. In order to see the results more clearly the calculation has been made as if the campaign had been a year of 350 working days and 15 days of rest for cleaning out the flues. The quantities given in Table III. will, therefore, be found altered in the ratio of 314 to 350. The value to the works of 100 kilograms of the dust collected is calculated on the supposition that the price of 100 kilograms of lead is 29 marks, and that the loss by the treatment is five per cent., and that the cost of treatment including transportation is 2.4 marks per 100 kilograms. The value of the silver is included in the calculation.

TABLE VI.

Sixth Campaign, reduced to 350 days.

In Section.		Dust.					Value of the Dust per 100 Square Meters of Wall Surface.	
Number.	Square Meter of Ground, Side Wall, and Arch Surface.	Weight.	Value.					
			Per 100 Kilos.		Total.			
	Square Meters.	Kilos.	Marks.	Pfen'gs	Marks.	Pfen'gs	Marks.	Pfen'gs
VI.	1321.09	72624	15	24	11067	90	837	84
VII.	3383.35	175974	15	13	26624	87	786	95
VIII.	3088.86	145963	13	65	19923	95	645	04
IX.	1077.33	30451	15	17	4619	42	428	76
X.	1165.30	44205	14	73	6511	40	558	74
XI.	1165.30	36491	14	71	5367	83	460	65
XII.	1009.80	30009	12	46	3739	12	370	27
XIII.	933.30	21846	14	26	3115	24	333	76
XIV.	1165.30	36120	12	26	4428	31	379	99
XV.	1165.30	31977	11	35	3629	39	311	42
XVI.	933.30	26432	11	02	2912	81	312	12
	16408.23	652092	14	10	91940	24	560	34

In order to compare the results of the seventh campaign with those of the sixth, the same calculation has been made and is given in Table VII., below:

TABLE VII.

Seventh Campaign, reduced to 350 days.

In Section.		Dust.					Value of the Dust per 100 Square Meters of Wall Surface.	
Number.	Square Meter of Ground, Side Wall, and Arch Surface.	Weight.	Value.					
			Per 100 Kilos.		Total.			
	Square Meters.	Kilos.	Marks.	Pfeng's	Marks.	Pfng	Marks.	Pfeng's
VI.	1321.09	57830.13	15	90	9194	99	696	15
VII.	3383.35	181371.77	15	76	28584	19	844	85
VIII.	3088.86	121460.17	15	69	19057	10	616	96
IX.	1077.33	44532.66	16	93	7539	38	699	82
X.	1165.30	41252 17	16	37	6752	98	579	50
XI.	1165 30	40350.04	16	00	6456	00	554	02
XII.	1009.80	36905.52	15	40	5683	45	562	83
XIII.	933.30	36003.39	15	64	5630	93	603	34
XIV.	1165.30	34363.14	13	59	4669	95	400	75
XV.	1165.30	43958.58	14	41	6334	43	543	60
XVI.	1733.30	54292.12	14	95	8116	67	468	28
	17208.23	692319.69	15	60	108020	08	627	72

In these tables Sections I. to V. have been omitted, both because they have given exceptionally favorable results and because the gases are only collected in the main flue at Section V. Section XVII. is also left out because of the unknown effect of the wall surface of the chimney.

To make these results of the sixth and seventh campaigns apparent to the eye, they have been graphically represented on Plate III. The abscissas indicate the number of square meters of wall surface contained in every section; the ordinates represent the total value of the dust collected in each section and also the value per 100 square meters of wall surface. Each section is thus represented by a rectangle which gives a graphic representation of the total quantity of wall surface contained in each, and the value of the material collected. These are printed on the middle line of the rectangle representing each section. In each rectangle there are two figures giving the value of the dust collected, the upper one being for the sixth and the lower for the seventh campaign. The lines of the sixth campaign are represented in full, while those of the seventh are represented as dotted. The ends of the middle ordinates are joined, making a zigzag line which is quite different for each one of the sections in the two campaigns; a curve representing these lines has been given, showing

the value of the dust collected for both the sixth and seventh campaigns.

During the seventh campaign no change in the quantity of wall surface was made except in Section XVI., where the wall surface was increased from 933 square meters to 1733 square meters. It is very remarkable, that, while between these two campaigns no change in the quantity of wall surface has been made except in Section XVI., all the weights and values have been altered by this single change; and that, while the flue has been made very much shorter by the cutting out the condensation-chambers X and Y, the wall surface has been so much increased by the addition of sheet-iron plates that, with the exception of Sections VI. and VIII., the value has in every section been increased, while the total value has been very largely increased. This is shown by the curve representing Section XVI. in the seventh campaign being very much higher than that of Section XVI. in the sixth campaign, making the total value of the dust collected in this section more than three times what it was in the former campaign while the surface has not been quite doubled. This shows beyond doubt that the quantity of material collected is proportional to the extent of wall surface, and that the cubical contents of the flue itself is of importance only as it allows of a maximum amount of surface in the shape of plates being introduced within it. It is also to be remarked that while the curve in the seventh campaign is much flatter it commenced in Section VI. with less value, and there seems, therefore, no doubt whatever that this method, which is not only cheap, so far as the installation is concerned, is also by far the most effective of any which has yet been devised for the collection of flue-dust, and notably for the condensation of the volatilized material. It is to be noticed that there are three separate causes which will make the curve flatter. The first of these is the decrease in value, owing to the complete separation of the particles mechanically carried off; the second is the decrease in value, owing to the reduction in temperature; and third, the decrease in the value of the gases, owing to the separation of the metallic particles held in suspension.

As is shown by the results, the first cause, that is the separation of the particles carried off mechanically, acts within a very short distance from the furnace, so that by the proper construction of the condensing plates, nearly the whole of the ore particles will be separated from the gases, not far from the furnaces themselves. There will remain then in the gases only the volatilized metals.

Some of the causes of the difficulty of the separation of the ore particles from the gases have been already discussed. It appears, however, that the curve might easily become a straight line if it were possible by the introduction of an infinite quantity of surface to condense the whole of the dust. It would seem from the discussion of these two curves that the influence of the reduction of temperature was not as great as it appeared to have been from the experiments made in the sixth campaign. It will, however, probably be found expedient still further to disengage the sides of the flue, both for convenience of repairs and convenience of access.

It appears from Table I., that the cost of the construction of a square meter of wall surface in the flat flue of Section IV., exclusive of the cost of the ground, was 9.976 marks. This calculation is made on the supposition that the cost of the ground for the square meter of wall surface was 0.44 marks; one square meter will, therefore, cost 10.20 marks, and 100 square meters will cost 1020 marks. In all these observations the condensing chambers X and Y, since they have cost so much for repairs, have been left out of the consideration altogether as defective, and have not been taken into the calculation.

The square meter of wall surface made of new sheet iron, No. 22 including the cost of erection, will not cost more than 0.75 marks. One hundred square meters would, therefore, cost 75 marks. In making up the cost of these two methods of getting surface, as is shown upon Plate III., 10 per cent. of the cost of construction has been charged for the sinking fund of the masonry walls, while for the sheet-iron surface, 20 per cent., which is a very large charge, is made. The yearly charge, then, for the sinking fund for the 100 square meters of masonry surface, would be 102 marks, while for the surface obtained by hanging in the sheet-iron plates it would only be 15 marks. The difference between the two is shown very decidedly in the lines representing the cost, Plate III. From the experiments which have already been made since the introduction of these sheet-iron plates in the flues, 20 per cent. seems to be a very exorbitant charge, although made very high purposely, in order to make the most disadvantageous comparison between the two systems. No perceptible alteration or wear has been shown after a use of five years, so that if less than 20 per cent. is charged, the line would go still lower than it now does, and it would seem to be the natural conclusion that the cheapest method would be to build short, large flues in which the maximum of wall surface was obtained by the intercalation

of these plates. All the experiments made up to the present time fully justify the conclusion, that not only is this the most economical method of saving a quantity of material which has hitherto gone to profit and loss, because it was supposed to be impossible to save it, but that it is also possible to reduce very largely the cost of the works by increasing the wall surface indefinitely at a very cheap rate. The most remarkable fact relating to these experiments is this, that by almost doubling the wall surface in the last section of the flue which is furthest removed from the works, where there was no probability that any material mechanically carried off by the gas would be still retained suspended in it, there is such a large amount of value obtained from the dust. This can only be attributed to the fact that the metallic material which is volatilized, and which is collected with such great difficulty, has been carried to that point and condensed there, and that without this increase of wall surface this large amount would have gone up the chimney and been entirely lost. It seems, therefore, that not only in all works where the flue-dust contains value should especial attention be given to collecting it, but that the quantity of metal which is actually volatilized, merits special attention.

When the values which represent the different sinking funds for the year are transferred to Plate III., and compared with the curve which shows the value of the dust collected in the different divisions of the flue, and these data are also compared with the very great value of the flue-dust collected, it is a matter of surprise that the collection of flue-dust in metallurgical works does not appear to have attracted more special interest than it has done, if only on account of its pecuniary importance.

THE DIVINING-ROD.

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THE extent to which the divining-rod is still used in this country for the detection of hidden treasure, mineral veins, or springs, is much greater than educated persons would be likely to suppose. For many years wells have frequently been located by its aid in New England, where the belief is widely extended among the farmers that in the hands of peculiarly gifted persons this instrument possesses special virtue. Large numbers of the oil wells of Pennsylvania

have been bored at points designated by the so-called "oil-smellers." More than one adept with this instrument is practising now in the Western mining region. I encountered, a few months ago, in Southern Colorado, a party of capitalists who were accompanied by such an expert, and whose purpose was to discover a mine, by his aid, and to buy the property thus made valuable. Still more recently, a paragraph in the Tombstone *Epitaph*, of Arizona, announced that a party of gentlemen from Chicago, whose names were given, had been scouring over the hills in the neighborhood of Tombstone, for more than a week, in company with an expert of Colorado, who had been employed to ascertain "with his well-known divining-rod" the localities of mineral wealth, and who had declared the existence of large bodies of ore in at least two places not yet developed. It is also reported, with what truth I do not know, that the Central Pacific and Southern Railroad companies have employed the divining-rod successfully in the discovery of water, and have located by this means their artesian wells in the desert. Last, but not least, a small book entitled *The Divining-Rod*, and published in Cleveland, in 1876, contains an essay on this subject, read before the Civil Engineers' Club of the Northwest, at Chicago, in 1875, by Mr. Charles Latimer, a well-known engineer who has had charge of several important railways, and who testifies in the most unqualified manner to the virtues of the divining-rod as a means of determining the position and the depth of subterranean water-courses, and claims to have discovered certain new and important laws of its operation connecting if not identifying it with the force of electricity.

These circumstances, taken together with the fact that the "dowsers," or experts with the rod, still enjoy considerable local authority in Cornwall, and that believers in its efficacy may still be encountered among the German miners (although I think in that country the faith is more nearly extinct than elsewhere), certainly justify me in regarding this subject as one not solely of historical interest. Yet a consideration of its history and literature will throw important light upon the question, whether the phenomena which it has presented, and continues to present, are to be ranked under the head of self-delusion, deliberate deceit, or both; or, on the other hand, indicate, after all reasonable deductions for human error and credulity, a residuum of important scientific truth.

Before sketching the history of this instrument, it will be well to say a few words concerning its form, material, and use. Yet this is a work of no little difficulty. The immense literature of the divin-

ing-rod shows nothing more clearly than the boundless confusions and contradictions of its advocates and professors. Of the dozen different schools of practice, each is necessarily obliged to reject many of the asserted principles and certified facts put forward by the rest.

The most common divining-rod, perhaps, has always been a forked branch of witch-hazel in the shape of the letter Y. This wood may have been selected because it forks in such a way as to give two branches of equal size, or because of its supposed affinity for springs of water. But other woods, such as peach, ash, pitch-pine, and even metals, have been recommended at different times, and different professors of the art have also varied the shape of the rod, employing sometimes a straight twig with a small fork only at one end, or an elastic twig or whalebone without any fork. The dowsing-rod used by the expert mentioned in the Tombstone *Epitaph*, is, I believe, an instrument made of two prongs of whalebone united in a stem which terminates in a case similar to a rifle-cartridge. The contents of this case are a secret. (Similar cases, used in the Middle Ages, are said to have contained mercury.) This rod, like the ordinary forked hazel switches, is held in the two hands, each grasping the extremity of a prong, with the fingers closed not too tightly and the palms upward, the shank or stem of the rod being horizontal or vertical, or variously inclined, according to the principles of the practitioner. When carried in this manner by the operator, walking over the surface of the ground, the rod is said to turn or dip above treasure, mineral veins, springs, etc.; but there is an elaborate and complicated science based upon the various degrees, directions, and force of this dipping. Unfortunately the rules as determined by one or another celebrated operator have been found not to work for his rivals or successors, so that each authority lays down rules of his own. The straight rods were either balanced in various ways on one or both hands, or sprung bow-like between the two hands. The most peculiar rod described in ancient books was made of two pieces of wood, one of which was pointed and the other provided in the end with a socket. This rod being delicately held was said to indicate the presence of the object sought for by a peculiar revolution of the point in the socket.

An inquiry into the uses of such rods leads us at once to the history of our subject, in the study of which it will appear that divining-rods were first used in antiquity mainly or wholly for moral purposes; that in the Middle Ages their employment was for a long period confined to the discovery of material objects; that towards

the end of the seventeenth century the moral use was again asserted, and that in the eighteenth century the divining-rod was relegated to the material sphere, and assumed the comparatively modest functions in the discharge of which it still lingers among us.

I would recommend to those who have not the means of an extended research the perusal of the book of Professor Fiske, of Harvard, on *Myths and Myth-makers* (Boston, 1873), in the second essay of which, on *The Descent of Fire,* this subject is treated in the light of comparative mythology; also the work of Louis Figuier, *Histoire du Merveilleux dans les Temps Modernes* (Paris, 1860), half of the second volume of which is devoted to the divining-rod; and, finally, the book of Chevreul, *La Baguette Divinatoire* (Paris, 1853), which is a conclusive summary from the standpoint of modern science and experiment. I do not mention the work of Mr. Baring-Gould, *Curious Myths of the Middle Ages,* which Professor Fiske compliments with frequent quotations, for the simple reason that Mr. Baring-Gould's essay on the divining-rod is made up almost wholly of portions of Figuier's work, often translated *verbatim* and without credit. A brief, interesting, and impartial discussion of the divining-rod from the standpoint of the Middle Ages, together with a curious engraving illustrating its use, will be found in the well-known work of Agricola (*De Re Metallica,* Basle, 1546), published in the sixteenth century both in Latin and in German, copies of which, though not very common, are still to be met with in the antiquarian bookstores of Europe. I believe the Library of the School of Mines, of Columbia College, contains a German copy. In the preparation of this paper I have made use of the Latin edition, which is the only one in my possession. An excellent summary of the subject, containing many curious details, will be found also in Professor Moritz Gaetzschmann's *Auf-und Untersuchung der Lagerstätten* (Freiberg, 1857). The Brooklyn Library contains a copy of a work entitled *Jacob's Rod: A Translation from the French of a Rare and Curious Work, A.D.* 1693, *on the Art of Finding Springs, Mines, and Minerals by means of the Hazel Rod. To which is Appended Researches with Proofs of the Existence of a More Certain and Far Higher Faculty, with Clear and Ample Instructions for Using it.* Published by the Translator: Thomas Welton, 13 Grafton street, Fitzroy Square, London. This book was published, I believe, in 1875. The title-page bears no date. The original French treatise, the translation of which occupies the first part, is probably the one entitled *La Verge de Jacob, ou l'Art de trouver les trésors,* which Figuier

(*Histoire*, etc., vol. ii., p. 257) speaks of as well-known to the adepts in occult sciences, and Chevreul (*La Baguette*, etc., p. 30) mentions as an example of the use of the term "Jacob's rod," in those sciences, to signify a rod possessing marvellous properties. The origin of this signification will be found in Genesis, xxx. I suspect that neither Figuier nor Chevreul had seen this book; both of them fail to give either the name of the author or the date of publication, an omission especially noticeable in the case of Chevreul, who is usually both full and careful in his references. The translator gives the date as 1693, and names the author as M. Baritel. Of the fidelity of the translation I have no guaranty except internal evidence, from which I judge that it is honest rather than intelligent. This translator, Mr. Welton, is himself a mesmerist and electro-biologist, and declares his wife to be possessed of clairvoyant powers, of the exercise of which he believes the discovery of water, metals, etc., to be but one subdivision. The object of his translation and "addenda" is to connect the ancient phenomena of rhabdomancy, the observations and theories of Reichenbach, the fanciful speculations of Bulwer-Lytton, and numerous modern wonders (accounts of which he extracts from the *Spiritual Magazine*), with his own and his wife's alleged experience.

To the works above named I am indebted for nearly all the facts cited in this paper, and for many quotations made at second hand.

Professor Fiske, following Dr. Kuhn, whose treatise on the *Descent of Fire* was published in Berlin in 1859, traces the divining-rod to a wide-spread Aryan myth, connected with the forked lightning. Without going so far back, we may find in written history many evidences of the use of the rod, not only as a symbol of earthly power, but also as the instrument of supernatural effects, and particularly of divination. It will be remembered that the Egyptian sorcerers confronted by Moses carried rods, as Moses and Aaron also did. The prophet Hosea denounces the use of rods for divination by the Jews (Hosea 4:2). According to another prophet (Ezekiel 21:26) the King of Babylon consulted rods or arrows to decide his course. The Scythians, Persians, and Medes used them. Herodotus says that the Scythians detected perjurers by means of rods. The word *Rhabdomancy*, originated by the Greeks, shows that they practised this art; and the magic power of the rods of Minerva, Circe, and Hermes or Mercury, is familiar to classical students. The *Lituus* of the Romans, with which the augurs divined, was apparently an arched rod. Cicero, who had himself been an augur, says in his

treatise on divination, that he does not see how two augurs, meeting in the street, could look each other in the face without laughing. At the end of the first book of this treatise he quotes a couplet from the old Latin poet Ennius, representing a person from whom a diviner had demanded a fee as replying to this demand, "I will pay you out of the treasures which you enable me to find." This ancient joke, by the way, has been adopted in all seriousness by the "oil-smellers" of Pennsylvania, who, as I am informed, are accustomed to locate oil wells on precisely this condition, receiving nothing if the well proves unsuccessful, and fifty dollars if oil is struck.

Marco Polo reports the use of rods or arrows for divination throughout the Orient, and a later traveller describes it among the Turks. Tacitus says that the ancient Germans used for this purpose branches of fruit-trees. One of their tribes, the Frisians, employed rods in church to detect murders. Finally, if we may trust Gonsalez de Mendoza, the Chinese, who seem to have had everything before anybody else, used pieces of wood for divination.

Thus we perceive that the application of the divining-rod in historical antiquity was mainly or wholly moral; that is, it was employed to detect guilt, decide future events, advise courses of action, etc., etc. There are but two passages which have been quoted to prove its use for physical purposes: one from Ctesias (*apud phot. bibl. cod.*) who speaks of a rod of the wood *Parebus*, which attracted gold, silver, other metals, stones and several other things; the other from Cicero (*De Officiis*, lib. i.) who says, "If we could obtain with the so-called divine rod everything pertaining to food and clothing" (*ad victum cultumque*), etc.

On the other hand, the silence of many authors is significant, as Chevreul has pointed out. Varro does not mention the use of the rod for the discovery of subterranean waters or metals. Vitruvius, discussing the means of discovering springs, says nothing of it. Pliny, in Book xxx. of his Natural History, omits it from his enumeration of magical arts and methods, and in Book xxxi., describing (after Vitruvius) the means of discovering springs, and in Book xxxiii., describing explorations for metals, is equally silent concerning it. Columella, Palladius, and in the sixth century Cassiodorus are likewise dumb, though the latter in one of his epistles (*Theodoric*, liii.) extols the utility of the professional water-discoverers. Even as late as 1569, a book printed in Orleans (*L'art et science de trouver les eaux et fontaines cachées sous terre autrement que par les moyens vulgaires des agriculteurs et architectes*, par Jacques Besson, Dauphi-

nois, mathématicien) contains no allusion to the rod. It is a curious circumstance that this work emanated from Dauphiny, the home, a century later, of the most famous diviners and water-discoverers.

But the alchemistic literature brings the physical uses of the divining-rod to the front. The first mention is usually credited to the *Novum Testamentum* of Basil Valentin, a Benedictine monk and hermeneutic philosopher of the 15th century. But it must be remembered that the existence, even, of this man is not beyond doubt. It is attested by Gadenus (*Historia Erfordiensis*, 1675), who says that Basil was living at the convent of St. Peter's at Erfurth in 1413. Yet the *Testamentum* was actually first printed at the beginning of the 17th century, though manuscript copies had been circulated earlier. Of these, Chevreul possesses one (a French translation) dated 1651, and from it quotes the famous passage according to which, at the time of the writer, the divining-rod was worn in the belt or the hat and was used to discover metals. Basil describes seven varieties of the rod, according to its different motions.

Whatever its antiquity, the use of the rod to discover hidden treasure or metallic ore became general in Germany, and was extended thence through Flanders, England, Sweden, France, Italy, and Spain, before the end of the 17th century. It must be remembered that in those days the practice of burying money and plate was universal. A rod that would discover buried treasure only would, at the present time, be of comparatively little value. We know well enough where the large masses of gold and silver are piled. It is not ignorance, but bolts and bars, that prevent our getting at them ; and a large class of the diviners of the Middle Ages would be obliged, if they lived to-day and practised their profession, to become burglars or cashiers.

The scientific explanation of the divining-rod at this period, like the scientific explanation of nearly all facts in chemistry and physics, was "affinity," a word under which was concealed a little science together with a vast amount of ignorance and superstition. Philip Melanchthon (1497–1560), the friend of Luther, adopted this theory to explain the effects of the divining-rod. We must confess that in an age when the attraction of the magnet for iron and of electrified amber for light bodies was known, but not understood, there was no necessary absurdity in supposing that similar phenomena might be exhibited by other classes of substances. And this natural presumption, joined with the inherent credulity of ignorance and the tendency to generalize upon imperfect data, caused a very

general acceptance of the alleged operations of the divining-rod as true, and consequently the promulgation of crude quasi-scientific theories to account for it. On the other hand, it must be remembered that the belief in demonic agencies was still active and all-pervading, so that when facts could not be scientifically explained they were at once referred to witchcraft or to the devil direct. So long as the discussion remained within the field of science, it was conducted with courage and candor; but when it entered the demonic domain, the boldest philosopher, unless he were willing to sell his soul to Satan, became dumb. This may explain the attitude of the great Agricola (*De Re Metallica*, lib. ii.), a keen observer and wise reasoner, who, after saying that the alleged virtues of the divining-rod are subject to much dispute, and stating both sides of the dispute with admirable clearness, demolishes in a few words the supposed analogies of magnetism and electricity, but declares that if the divining-rod derives any power from spells and incantations, that is a matter neither permissible nor agreeable for him to discuss. He proceeds, moreover, to assert as the general result of experience in his time that the professors of the divining-rod, though they sometimes succeed in discovering veins, quite as frequently fail, and have to dig like other people if they wish to find anything. Wherefore, he advises the respectable and sober miner to study the indications of nature, and then dig at once, without further fooling. In the quaint woodcut which accompanies this passage a miner is represented in the background as cutting his hazel twig; while another in the foreground is proceeding with it in due form for the discovery of the mine; and (whether in sarcasm or not, I do not undertake to say) at the very point to which the latter is steering, two of Agricola's "good and sober" miners have already found ore by the homely process of digging.

Paracelsus (1495–1541) condemns in his works, as uncertain, illusory and unlawful, the use of the rod. His disciples did not uniformly agree with this view. Goclenius, author of *Essays on the Virtue of Plants and the Unguent of Arms*, believes in the efficacy of the rod and does not condemn its use. Libavius, author of the *Syntagma arcanorum chimicorum* (died 1616) believed in it from experience, and explains its action by sympathetic affinity. This theory, already announced by Melanchthon, was also held by his son-in-law Peucer, by Porta (*Magia Naturalis*, 1569, lib. xx., cap. viii.), by Keckermann (1573–1609, *Systemata Physica*, lib. i., cap. viii.), by the author of one of the discourses published with those of

Maiolus, Bishop of Volturara (1614), and by Michael Mayer, the prolific author of alchemistic allegory (*Verum inventum, hoc est munera Germaniæ*, cap. iv.), who, describing the invention of gunpowder in Germany and the use of hazel-charcoal in its original manufacture, mentions the sympathy which hazel-wood has for metals, and its consequent employment in the form of the divining-rod.

On the other hand, the Jesuit father Laurentius Forer (*Viridarium philosophicum seu disputationes de selectis in philosophiâ materiis*, 1624) condemns the use of the rod as a superstitious practice. We must distinguish therefore three different views of the question; two of which accepted the efficacy of the rod as proved, and ascribed it respectively to a physical property of the rod, and to demonic agency, while the third discredited the alleged facts, and pronounced the practice to be a superstition.

A fourth view was indeed advanced, according to which the operator, as well as the rod, was the recipient of a divinely given faculty. It was no doubt with the purpose of avoiding the odium attached to dealings with the Evil One that the professors of this science, particularly in Germany, surrounded it with ceremonies and formulas of a highly pious character. It is true that the rules sometimes prescribed for the cutting of the twig partook largely of heathen sorcery and astrology. They were indeed, to some extent, unconscious reminiscences of the old Scandinavian, and even of the Aryan, mythology. But this was atoned for when the rod was duly Christianized by baptism, being laid for this purpose in the bed with a newly baptized child, by whose Christian name it was afterwards addressed. The following formula, cited by Gaetzschmann, may serve as an example. "In the name of the Father, and of the Son, and of the Holy Ghost, I adjure thee, Augusta Carolina, that thou tell me, so pure and true as Mary the Virgin was, who bore our Lord Jesus Christ, how many fathoms is it from here to the ore?" In this case, the rod was expected to reply by dipping a certain number of times, corresponding to the number of fathoms.

Such devices, however, were not everywhere successful in diverting from the practitioners of this occult science the evil name of sorcery. A striking and pathetic instance is furnished in the seventeenth century by the history of the Baron and Baroness Beausoleil. The Baron, born in Brabant, devoted himself to mineralogy and mining, and became, undoubtedly, one of the foremost mine-engineers of his time. He visited and studied the mines of Germany, Hungary, Bohemia, Tyrol, Silesia, Moravia, Poland, Sweden, Italy, Spain, Scot-

land, England and France. The emperors Rudolph and Matthias appointed him counsellor and commissary-general of the mines of Hungary. The archduke Leopold made him director of the mines of Tyrol and Trent. The dukes of Bavaria, Neuburg, and Cleves gave him the same title. Finally, the Pope did the same for all the papal states. He appears to have amassed from these various employments a considerable fortune.

In 1600 he was engaged by the comptroller-general of the mines of France to open mines in Languedoc and some other provinces, and in 1626 this commission was still further extended. During this period he met and married his wife, who devoted herself with enthusiasm to his profession, studying and travelling extensively with him in Germany, Italy, Sweden, and perhaps Spain. They even made a voyage to the shores of the New World. In 1627 their house was robbed under the legal forms of search on the charge of sorcery preferred by a local official. Their loss was estimated at one hundred thousand crowns. They easily obtained acquittal of the charge; but it is an instructive commentary on the justice of the time that they never were able to recover their property. They went to Hungary, but returned to France in 1632 under a new commission from Louis XIII. In this year the baroness, who was an accomplished author, published an account of one hundred and fifty mines already discovered in France, and of some medicinal springs. They expended, in further explorations, nearly the whole of their fortune, but were unable, in the face of their jealous rivals and enemies, to obtain from the government the grants which had been promised them, and by means of which they expected to reimburse themselves. Finally, the baroness published a work, addressed to Richelieu, and entitled *The Restitution of Pluto* (reprinted at Paris in 1779), in which, with eloquent indignation, she declared the deserts of her husband and herself, and asserted their right to the rewards promised them, urging the cardinal-minister at the same time, by every consideration of the glory and greatness of France, to encourage the development of its mineral resources. Unfortunately, in this work she furnished new material for the slanderous accusation of sorcery. In magnifying the art of discovering mines and springs, and the skill required for this purpose, she gives a description of the means employed, showing that these hidden treasures are to be detected,

1. By digging, which is the least important way;
2. By the herbs and plants which grow above springs of water;

3. By the taste of the waters which flow from them;
4. By the vapors which arise from them at sunrise;
5. By the use of sixteen scientific instruments and of seven rods (the seven rods of Basil Valentin) connected with the seven planets, etc.

The first four means were undoubtedly real and really employed. Under the fifth head we have an illustration of what is so common in the alchemistic and other mediæval writers, namely, the covering of the facts of nature and the methods of investigation with assumed mystery, to hide them from the vulgar. So long as the baron and baroness were spending their own money for the good of the state, they were permitted to go on, and even received complimentary notices from time to time, which, indeed, could not be withheld from persons of such eminent reputation. But when they became troublesome in their demands for more substantial favors and came into collision with the "rings" which infested the kingdom, the charges of sorcery renewed against them furnished a convenient pretext for putting them out of the way. Richelieu may even have supposed that he was behaving in this case with lenity, since instead of having them burned to death, as he did with another sorcerer of the same period, he only put the baron in the Bastille (1642) and his wife in Vincennes, where they soon (about 1645) died in destitution and misery, victims not so much of the superstition as of the corruption of the times.

It will be noted that the treatise of the baroness did not claim from the divining-rod any moral virtue. What the Beausoleils appear to have done for this instrument was to bring forward its use in the discovery of springs as well as metals. The literature of that period seems to ignore in the main any powers of the rod in prophecy or moral discrimination.

The Jesuit father, Cæsius (*Mineralogia*, 1636), inclines to deny the efficacy of the rod.

Robert Fludd (*Philosophia moysaica*, 1638), after mentioning the sympathy existing between the crab or oyster and the moon, between the rue and the fig-tree, between myrtle and the pomegranate, adduces as an instance of similar sympathy between plants and minerals the dipping of a hazel-rod over a vein of silver or gold.

The celebrated chemist, Rudolph Glauber (*Pars seconda Operis mineralis*, 1652), affirms from experience, and attributes to a physical property, the efficacy of the rod in exploring for metals.

The Jesuit father, Jean François (*Science des Eaux*, 1653), seems

to admit the power of the rod to discover springs, but condemns its use.

The erudite Jesuit father, Kircher (*De Arte Magnetica*, 1654, *De Mundo Subterraneo*, 1678), having proved by experiment that rods of wood alleged to be sympathetic with certain metals, were, when balanced upon pivots, not at all affected by the proximity of these metals, concluded that the sympathy was chimerical. In his later work he declared roundly, that, if the movement of the rod did not proceed from a joke or a cheat on the part of the operator, it was not natural, and ridiculed those who fancied it could be caused by a vapor disengaged from the metal.

Edo Neuhusius (*Sacrorum fatidicus*, 1658) believes in the working of the rod, and attributes it to a sympathy, or to the stars, or some other cause.

The Jesuit father, Gaspard Schott (*Physica curiosa*, 1662), pronounces the use of the rod superstitious, or rather diabolical. But he adds in a footnote that pious and honest men have assured him both with regard to the turning of the rod and with regard to the striking of the hours by a ring suspended within a glass (*pulsum annuli filo intra scyphum suspensi et horas indicantis*), that the experiment does not always succeed, and hence he will not assert that the demon is always acting. The argument appears to be, that if the devil had it in hand, it would not fail. The pious and honest men aforesaid also protested that the phenomenon was natural and not due to fraud or fancy. "*Sed nondum persuaserunt*," pithily concludes Schott. The passage is noteworthy as containing a reference to the wonderful pendulum, which became, at a later day, the subject of scientific treatises, and still survives as a puzzle and amusement for children of all growths.

Sylvester Rattray (*Theatrum sympatheticum*, 1662) believes in the sympathy of vegetables with minerals. According to him, the hazel is suitable for the discovery of silver, wild pine for lead, olive and palm for gold and silver.

It was in 1666 that Robert Boyle put the question as member of the Royal Society of London, whether the divining-rod is really moved by the proximity of metal—a pertinent inquiry which no one seems to have answered by authoritative and thorough experiments, unless we may accept as sufficient those of Kircher above mentioned. The accumulation of contradictory testimony from witnesses of all degrees of competency went on.

Matthias Willenius, a German author, published in 1671 or 1672

a book called *A True Account of the Rod of Mercury,* in which, as the title indicates, he appealed to astrology for the partial explanation of his theme, asserting that the influence of the stars under which the operator is born, contributes to the turning of the rod over metals, "by the effect of the harmony established between heaven and earth."

Frommann (*Tractatus de fascinatione,* 1674) says that, after long hesitation, he has decided that the use of the rod is lawful.

The Jesuit father, Dechales (*De Fontibus naturalibus,* 1674), inclines to the same opinion, and speaks of the hazel as having been in all times (*omni tempore*) used as an index to springs. This is a curious illustration of the rapidity with which a tradition may come to be considered immemorial. In fact, if we except the striking of the rock in the desert by Moses—which is certainly not a case in point—the first trace of the use of the rod for discovering springs, is in the works of the Beausoleils, scarcely fifty years before Dechales wrote his treatise.

Le Royer, a lawyer of Rouen, published in 1674 his *Traité du bâton universal,* and in 1677 his *Traité des influences et des vertus occultes des êtres terrestres.* He declares that the rod by its sympathetic virtue can discover all hidden objects, metals, springs, etc. But he ascribes to it no moral power.

The Abbé Hirnhaïn (*De typho generis humani, sive scientiarum humanarum inani ac ventoso humore,* etc., 1676), while scoffing at many reviewed beliefs, admits without question efficacy of the divining-rod.

St. Romain (*La Science naturelle degagée des chimères de l'école,* 1679) was one of the first believers in the rod to reject the sympathies and antipathies and to substitute the Cartesian corpuscular hypothesis—of which I shall have more to say hereafter.

Finally, the celebrated botanist, Ray (*Histoire des Plantes,* 1686), classed the divining-rod among superstitions.

This review of the literature of the subject has brought us to the end of an important period, namely, that in which the physical effects of the rod were exclusively discussed, its earlier uses for general divination having gone out of fashion and recollection. Indeed, any attempt to maintain these would have incurred the censure of the church, which would have settled at once the vexed question of agency by denouncing this unauthorized intrusion upon its spiritual prerogative as diabolic. This is indeed what speedily happened, as we shall see. The lost doctrine of moral power reappeared, not among the learned, but out of the obscure mass of the people. In

the province of Dauphiny, in thesouth of France, the practice of the divining-rod, introduced perhaps by the Beausoleils, had become, fifty years after their death, an art followed by many experts, who were called *Hommes à Baguette.* They were employed to find springs of water, hidden treasure, mines, etc., and also to detect criminals, and even to settle disputes as to boundaries when the landmarks were gone. Two farmers, for instance, having a dispute as to the boundary between their farms, instead of going to a lawyer or judge, would send for a diviner. He, walking over the disputed ground, would indicate by the dipping of his rod the spot where the old landmark formerly stood; and this decision was accepted without appeal. Considering the expense of litigation in all times, and the peculiar character of the justice which at that time was sold so dear and worth so little, we may fairly say that whatever be the merits of the divining-rod, the peasants of Dauphiny acted wisely in employing it.

In 1692 a mysterious murder was committed at Lyons. A wine merchant and his wife were found dead, lying in their cellar near the bloody axe with which they had been slain. A neighbor urged the authorities (who seem to have had no clue to the murderers) to employ a rich peasant of Dauphiny, already famous as an expert with the divining-rod. This man, Jacques Aymar by name, was sent for—or rather it was not necessary to send for him, since he proved to be already on hand in the city, by the time it was decided to engage his services. This fact is significant, as giving the key to what turned out to be an extraordinary piece of clever detective work. A careful analysis of the numerous official and other records of this case shows it to be quite possible that the diviner had obtained important clues before he was publicly set to work. He first demanded to be taken to the scene of the crime that he might get his "impression." This consisted in a sort of shuddering, accompanied with signs of agitation, pain and exhaustion, and manifesting itself besides in the dipping of his rod. This took place at the spot where the bodies had lain, the spot where the axe was found, and also in the shop above, at various points which he declared to have been occupied or touched by the criminals. Having thus obtained a thorough impression, after the fashion of a bloodhound getting a scent, he started, though it was night, and followed with his rod the alleged course of the fugitives, passing without hesitation through many unlikely places, as far as one of the gates of the city. Next morning he resumed the trail and tracked it to the house of a

gardener, where he declared that the criminals, either two or three in number, had stopped. The gardener and his wife denied all knowledge of them, and Aymar, consulting his rod, declared that neither had touched the murderer. But the rod dipped violently over two young children of the house, who thereupon confessed that three men had stopped there the day before, and had drunk wine at a table, which, by the way, had also been indicated by the rod. The children said they had kept this a secret because they feared being punished for leaving the door unlocked while their parents were away. After some further delays and preliminary tests, the magistrates determined to let Aymar pursue the murderers. He declared that they had taken a boat down the Rhone, and he followed them with an escort in the same manner, landing from time to time at different points where he said they had stopped. His pursuit was continued for a number of days with various interruptions, the assigned causes of which seem to have been sometimes but pretexts, and permit the suspicion that the intervals were employed by him in getting information in other ways. However this may be, he finally brought up at the prison of Beaucoire, and after applying his rod in succession to the inmates, pointed out as one of the Lyons murderers a hunchback, recently arrested for larceny. This man, being taken back to Lyons, was recognized at several points on the road as having passed just after the murder, and finally, frightened by the accumulated evidence against him, made a full confession, and was subsequently broken alive. The other two murderers Aymar professed to follow to the sea and at sea along the coast, until, as he alleged, they escaped from the kingdom.

So long as there was no doubt of Aymar's sincerity, this discovery of the criminal by the aid of the divining-rod seemed indeed marvellous. But it is not more wonderful than many detective operations in which the rod has played no part; and it is easy to trace the possible or probable methods which he employed. If, for instance, during the period just preceding his engagement by the magistrates, he had, in coming to town from his residence, fourteen leagues distant, or in hanging about the town, where everybody was talking of the crime, picked up in any way the circumstances of the three fugitives entering the house where the children were, it is almost inevitable that he would have obtained also some general description of their appearance, and I need scarcely remark, that the subsequent tracking of a hunchback would be no very difficult matter. It should be added here, that the judges who sentenced the hunchback, explicitly

declared that they attached no weight to the indications of the rod as direct evidence of his guilt, but condemned him wholly upon his own confession, confirmed by abundant circumstantial evidence.

But this achievement of the rod, attested as it was by official records and by the public confession and execution of the criminal, made a great sensation in France; and Aymar was called to Paris, where both the court and the *savants* interested themselves greatly in his mysterious powers. Many marvellous feats are reported of him there; but the shrewd and rigorous experiments of the Prince de Condé exposed the emptiness of his pretensions. It was Aymar's claim that his rod was sensitive to the particular object which he was at the time seeking. When he sought a given murderer the track of some other murderer would not divert it. When he was pursuing a criminal he could not be led astray by subterranean water or treasure. If he felt these things in passing, his feeling was nevertheless distinguishable from that connected with his intention, etc. He could, at will, seek any given object, and when doing so could not be deceived. Unfortunately for this claim the tests of the Prince deceived him very often. For instance, a purse of money was shown him, and after he had got his "impression" of it, it was taken out to be buried in the garden, but instead of burying it, the person who had it kept it in his pocket. Aymar proceeded to the garden, and, undisturbed by the immediate neighborhood of the money in the pocket of a bystander, located the spot where he said it was buried. In another case he detected the gold of the gilding of a chair which was covered so as to permit a glimpse of its ornaments, but he sat on a similar chair, and walked through a saloon containing many of them, all completely covered, without discovering any gold. In another case a window was designedly broken in a palace. Aymar was sent for to trace the thief, who, he was informed, had recently stolen some money from the palace. His rod promptly indicated the broken window as the road by which the thief had entered, and he proceeded to trace also the route of flight, although no such theft had ever occurred. But so long as these and similar failures were not made generally public, Aymar continued to enjoy much celebrity, and no doubt it was enough to turn the head of a peasant to be the object of such attention. Growing more audacious, he undertook to reveal character with his rod, and on one occasion, having received a fee from a gentleman of the court, with the request that he would discover whether the gentleman's sweetheart was true to him, he sent for the lady's servant, and demanded of him another fee as a condition of certifying

her virtue. Scandals of this kind became so bad that the Prince de Condé publicly exposed Aymar, and he returned to his home. On the way, however, in passing through a village he took occasion to designate five or six of the most respectable houses as the abodes of wicked women, which made a great uproar. I wish I could say that nothing more was afterwards heard of him; but unfortunately it appears that, as late as 1703, this man was employed during the civil war to point out with his divining-rod Protestants for massacre, under the plea of punishment for crimes they had committed.

We find connected with the exploits of Jacques Aymar a new theoretical explanation of the divining-rod. Many persons of more or less scientific training, not doubting the honesty of the man and the genuineness of the sensations which he manifested, cross-questioned him on the subject, and thus accumulated a mass of supposed data for the formulation of the natural law underlying these phenomena. It was at this time that the Cartesian philosophy was dominant in France, and the "subtle matter," "corpuscles," "animal spirits," and "vortices" of Descartes, furnished convenient hypotheses to explain almost anything. The two doctors of Lyons first supplied such hypotheses to the case of Aymar, but the subject was treated at still greater length by the Abbé de Vallemont, in his treatise on the divining-rod entitled *Physique Occulte*, and published in 1693. In this work he declares that by insensible transpiration particles escape continually from our bodies, that such particles pursue a vertical direction, and strike the divining-rod, which is thus caused to move up and down, assuming a line parallel to the path of the corpuscles. The holder of the rod receives corpuscular effluvia from other human bodies, and various substances, and communicates them through his pores to the rod, thus producing also a movement of revolution. The difference of the skin in different people results in various degrees of susceptibility to particular impressions, but Aymar was, according to the abbé, possessed of an epidermis which could receive all kinds of impressions without confounding them. The abbé says that there is a difference of form among the corpuscular effluvia of springs, minerals, bodies of thieves, those of assassins, those of naughty women, those of landmarks, etc., etc.; in other words he recognizes the existence of aqueous matter, larcenous matter, murderous matter, etc., and the last-named variety was the only one which produced upon Aymar very painful impressions. This was due, according to his scientific expounder, to the vehemence of remorse which pervades the corpuscles

of an assassin. The fact asserted by Aymar that he had detected and followed the trail of a murderer twenty-five years after the murder, and the fact that in almost every instance he necessarily began his researches a day or two after the crime—to say nothing of the cases in which he determined the locality of the landmarks which had been missing for an immemorial period, forced the abbé to a wild hypothesis of the extraordinary levity of the corpuscles, by virtue of which they remained a long time suspended in the air in spite of rain, wind, and even other corpuscles of later origin.

Father Lebrun, in a pamphlet on *The Illusions of Philosophers Concerning the Divining-rod,* printed at Paris in 1693, seriously refuted the system of Vallemont. This pamphlet was republished in the third volume of Lebrun's *Critical History of Superstitious Practices* (Paris, 1702).

But Father Lebrun and a large proportion of those who took part in the discussion rejected the scientific theory altogether, and attributed the facts to Satan. It was asserted that not only wicked people might obtain the divining power by a league with the devil, but that such an alliance might be made unconsciously, and that the power might be conferred upon an unwilling subject, as a means of ruin to his soul. Several cases are described at length, in which persons in whose hands the divining-rod pointed out springs, etc., had been by prayer and fasting and the help of their spiritual advisers, delivered from this dangerous gift. The authorities of the church favored this view, at least so far as any moral uses of the divining-rod were concerned. In 1701 the Inquisition of Rome condemned the divining-rod and all writings in support of it.

I condense from M. Chevreul's book the following list of the principal authors on the subject, for the period now under consideration.

Dr. Chauvin of Lyons (a letter to the Marquise de Senozan, dated September 22, 1692, published in the brochure *Superstitions anciennes et modernes*, Amsterdam, 1733; also in an appendix to the 2d edition of Lebrun's *Histoire critique des pratiques superstitieuses*).

Dr. Pierre Garnier of Lyons (a letter to M. de Sève, published November 10, 1692, at Lyons). This, like the letter of Dr. Chauvin, advanced the corpuscular hypothesis.

Two anonymous letters concerning the divining-rod, published in the *Mercure* of January and February, 1693. The first combats the corpuscular hypothesis; the second argues that, although this explanation is to be rejected, there is, nevertheless, nothing supernatural,

magical or diabolic about the phenomena, and that they are probably to be referred to physical causes as yet unknown.

M. de Couriers, a blind man and thorough partisan of the divining-rod (a letter in the *Mercure* of March, 1693).

M. L. de Vallemont, priest and doctor of theology (*Physique occulte, ou Traité de la baguette divinatoire et de son utilité pour la découverte des sources d'eau, des minières, des trésors cachés, des voleurs et des meurtriers fugitifs*, Paris, 1693, 12mo. 608 pp.). The argument of this book has been summarized above. Its purpose was to diminish the category of "occult" things by showing that the phenomena of the rod, like those of magnetism and electricity, were explicable by the physical corpuscular hypothesis.

Two letters published in the *Mercure* for April, 1693, by order of the Prince de Condé. One is anonymous; the other is addressed by M. Robert, *procureur du roi*, to Father de Chevigny. These are the documents which record the failures of Aymar; and the second concludes as follows: "His Serene Highness desires the assurance to be given to undeceive the public, that the rod of J. Aymar is nothing but an illusion and a chimerical invention. These are the Prince's words."

Father Lebrun (*Lettres qui découvrent l'illusion des philosophes sur la baguettes, et qui détruisent leurs systèmes*, Paris, 1693; also *Histoire critique des pratiques superstitieuses qui ont seduit les peuples et embarrassé les savants*, Rouen and Paris, 1702). These publications have been alluded to above. The letters comprise an interesting correspondence among Father Lebrun and three of the foremost *savants* of France, Father Malebranche, the Abbé de Rancé (the celebrated Abbé de la Trappe), and the Abbé Pirot, chancellor of the University of Paris. Lebrun (writing before the Lyons murders) narrates the alleged powers and performances of the diviners of Dauphiny, and asks Malebranche what he thinks of the matter. The latter, reasoning acutely on the data offered, decides that, as to physical objects (*e. g.* springs), if the action of the rod is real, water on the surface must agitate it more powerfully than water underground, also that it cannot be possible by any natural law to distinguish between the action of a small spring near the surface and a larger spring lying deeper. As to moral effects (discovery of murderers, missing landmarks, etc.), he concludes that if the rod really does this without fraud, it can only be from a supernatural cause (presumably demonic), and that the use of the rod is therefore to be condemned. Lebrun rejoins, agreeing with this view as to the moral effects, but

suggesting the corpuscular hypothesis as to material objects. A second letter of Malebranche declines to yield this point, and positively ascribes the whole thing to the devil. Meanwhile, the Abbé de la Trappe consulted by Malebranche, and (like the latter) assuming for the sake of the argument, but not accepting fully the reality of the phenomena, says the discovery of murderers, etc., must be ascribed to Satan, but the physical effects may be the result of a physical cause. Nevertheless, the use of the divining-rod should be discouraged altogether on religious grounds. Chancellor Pirot takes the same position, saying that the curés should forbid this practice as unlawful.

In his *Histoire Critique*, Father Lebrun gives a large number of instances in which the divining-rod has failed. He cites the provost of the Isle of France, who testified that he had often employed experts with the rod, both to detect criminals and to discover springs, and had never found one in whose hands the instrument was not "often variable and very often false." He shows the fundamental contradiction between two schools of practitioners, one of which declared that touching the rod with the same substance as the hidden substance which was causing it to move, would stop the motion; while the other declared that this proceeding augmented the motion. The conclusion of the argument is, that the phenomena of the rod (which Father Lebrun appears to believe are sometimes free from conscious imposture) are due to an intelligent cause of some kind, and that this cause must be satanic.

Father Ménestrier (*Indications de la baguette pour découvrir les sources d'eau, les métaux càchés, les vols, les bornes déplacées, les assassinats*, etc., published at the end of the author's *Philosophie des images énigmatiques*, Lyons, 1694). This author takes the same view as the preceding.

M. Baritel (*La Verge de Jacob, ou L'art de trouver des trésors*, 1693). The translation of this book by Thomas Welton has been already mentioned. The author appears to hold the corpuscular theory of the Abbé Vallemont, with the addition (which I do not find in any of the views of Vallemont's book), that he ascribes the capacity of different men in the use of the rod to the effect of the planets under which they were born, and defines this effect to consist in opening the pores of some more than others, and filling some more than others with "active particles," which being crowded out through the aforesaid open pores by the intrusion of exterior particles (from springs, metals, murderers, stolen goods, boundary lines, etc.),

powerfully affect the rod. Whoever has from his favorable stars both particles and pores galore, can discover with the rod anything he reasonably seeks. But he who has "only plenitude of particles with closed pores," will be sensitive to certain things only, to wit, such as move him most strongly, because the particles emanating from them violently eject *his* interior particles in spite of his less abundantly perforated epidermis.

The condemnation expressed by so many ecclesiastical authorities and by the Inquisition (October 26, 1701) undoubtedly checked the use of the divining-rod for moral purposes. At least we hear little of such applications in the eighteenth century. But believers in the rod were still numerous, and practitioners abounded, particularly in Dauphiny. The discoveries of Galvani put into the hands of the crude science of the day the materials for a new hypothesis, which was first applied to the so-called hydroscopes or water-diviners. One of the most celebrated of these, Bartholemy Bleton, was born in Dauphiny in 1750, and in 1780 was called to Lorraine by Dr. Thouvenel, who wished to study a good specimen of this art. The doctor, like his predecessors a hundred years before, tried credulous experiments and asked questions in abundance, and obtained a mass of supposed facts, out of which he immediately made a book, published in 1781, and called *Mémoire physique et medicinal montrant des rapports évidents entre les phénomènes de la baguette divinatoire du magnetisme et de l'électricité.* It would be useless to give the voluminous details of his investigation. The following points are, however, especially noteworthy. In the first place, Bleton apparently did not profess to discover immaterial qualities or facts, but chiefly confined himself to the detection of running water. In the second place, he frankly avowed that the rod possessed no power in itself by virtue of its form or material, and that it was merely an index, outwardly exhibiting to the spectators his inward feeling. This feeling the doctor declared to be a tremor, attacking first the diaphragm and communicating itself through the body and hands to the rod. In the third place this tremor was found by Dr. Thouvenel to be weakened, though not destroyed, when Bleton was on a tree or ladder or another person's shoulder, instead of the ground, or when he touched electrified substances; but the tremor and also the movement of the rod were completely stopped when Bleton was insulated from the ground. Upon facts of this kind he based his electrical theory. I remark, by the way, that the observations and the theory of Mr. Latimer, in his recent work on the divining-rod, already men-

tioned, recall in a striking manner the performances of Bleton and the theory of Thouvenel. Mr. Latimer claims to have made the new discovery that the effect of the divining-rod is destroyed by insulating the practitioner, as for instance, by placing him upon a platform supported by glass bottles. If he had known how thoroughly this claim had been examined and refuted, almost exactly one hundred years ago, he would have had less faith in its novelty and value.

Thouvenel's book made no little sensation, and in 1782 Bleton was called to Paris, where a remarkable series of experimental tests were applied to him. A newspaper report of the day declares that in the presence of many thousands of spectators he followed a subterranean aqueduct in the garden of the Luxemburg for fifteen thousand yards without a mistake. The chief engineer of the water-works is reported to have said that the trace was so accurate, that if the maps of his office had been lost, Bleton's footsteps would have constituted a complete survey to replace them. It is just possible that the *Journal de Paris* was tempted to make a sensation of this case, and it is also quite possible that a keen observer might notice indications other than those of his own diaphragm, by which he could follow the line of buried pipes. A large number of experiments, more calmly reported, certainly do not sustain the enthusiasm of this account. It was found, for instance, that Bleton often passed over running water, when blindfold, without noticing it; and that when taken several times over the same course he would not point out accurately each time the spots which he had previously marked. For example, of sixteen points once indicated, he recognized with the rod on the second round but eight and missed the other eight. A single point to which he was repeatedly brought blindfold, he indicated three times and missed three times. Of seven channels of running water which he was made to cross repeatedly, he indicated one once in four times, another once in four times, and another once in three times, while still another, which he crossed in two spots, affected his diaphragm at one crossing, and not at all at the other. The insulation experiment was repeated by a physician at Paris. At a point where Bleton's rod was powerfully affected by alleged subterranean water, he was mounted upon a stool with glass legs, and immediately the rod ceased to be affected. When the stool was removed, however, and he stood upon the ground, the rod resumed its sensitiveness. But Dr. Charles, who conducted this experiment, took occasion, while Bleton stood upon the stool, to bring the top, without his knowledge, into electrical communication with the earth by means

of a good conductor, thus destroying the insulation completely, though the hydroscopist supposed it still to exist. Under these circumstances, the rod remained inactive, and the destruction of insulation did not produce the slightest result. This was declared at the time to be a proof of Bleton's charlatanry; but, as we shall see hereafter, it is equally consistent with the hypothesis of unconscious mental and muscular action.

As a final test of Bleton's capacity as a hydroscopist, he was taken blindfold into the new church of Saint Genevieve, where there was known to be no water for one hundred feet below the floor, the vaults, foundations, etc., actually extending all that distance below. Here he professed to discover at numerous points large and small streams of water. Thouvenel subsequently asserted that his *protégé* had been affected by currents of damp air circulating in the cellar, but this explanation was universally considered as a desperate attempt to maintain a theory already brought into discredit by experimental tests. Bleton, however, though he ceased to be seriously respected by impartial scientists, continued to receive much attention, and to do a thriving business, both in Paris and subsequently in the provinces. Here, however, he no longer worked blindfold or professed to see with his diaphragm. He proceeded, like the ordinary water-diviners, with open eyes, studying all the natural indications, and coming to his decisions with abundant leisure; and under these circumstances it is beyond doubt that he rendered many valuable services to landed proprietors by successfully locating wells. In many cases, however, he failed entirely, and it is reported that even in those in which he succeeded, he was seldom right as to the depth at which water would be found or the quantity which would be obtained. It should be mentioned that in Dauphiny, where Bleton discovered a large number of springs, he was regarded with an esteem never given to Aymar and some other famous hydroscopists. In other words, the people who knew most about the art of discovering water, pronounced Bleton to be a real expert, while they believed Aymar and Parangue (of whom a word presently) to be more or less charlatans. A review of all the facts leaves little doubt that in Bleton's case there was an unusually large proportion of the skill of the prospector, combined with rather less than usual of the mysterious claims of the wizard.

Concerning Jean Jacques Parangue, mentioned above, it will be sufficient to say that he was born in 1760, near Marseilles, was said to have been peculiarly sensitive as a child to the presence of sub-

terranean waters, and became famous as a hydroscopist; but he used no rod at all, and the scientific theory advanced by his friends was one of clairvoyance. His eyes were described as very peculiar, and it was asserted that he saw water through rocks, earth or masonry, but, strangely enough, not through wood, crystal or glass. Like Bleton, he often deceived himself as to the volume and depths of the springs he discovered.

Dr. Thouvenel never saw Parangue, but defended him against the incredulity of the physicists, and undertook to show that the phenomena of clairvoyance even was merely a case under his electrical theory. According to his explanation the delicate nerves of the eyes were affected by the electrical currents traversing the body, and therefore the clairvoyant really experienced the sensation of vision by an internal, not an external excitation. Those who have read the admirable treatise of the late Dr. Clarke upon *Pseudopia* will notice with interest that in this case Dr. Thouvenel, explaining imaginary facts by an untenable hypothesis, nevertheless came very near a true physical theory of visions.

The worthy doctor emigrated at the time of the French Revolution, and carried with him to Italy another Dauphinese hydroscope named Pennet, whom he exhibited from city to city in support of his electrical theory. Pennet professed to find with his rod not only water, but buried metals and coal. I will not go at any length into the experiments. Some of them were striking and successful, and impressed even such *savants* as Spallanzani, more or less predisposed to expect discoveries in the new domain of animal magnetism. In many other cases, however, the experiments failed. For instance, in a trial of three days, at Padua, before a commission of *savants*, Pennet promenaded for two hours on the first day in a garden in which had been buried at different points, four metallic masses and a thousand pounds of coal. He could not find the metals at all, and only after much difficulty indicated the coal. On the second day his ill success was equally marked. Finally, on the third day, of three metallic deposits he failed to find the first, came pretty near the second without exactly hitting it, and found the third. The area covered by the search was only 840 square feet. Upon this test, Spallanzani revoked his favorable opinion. But at Florence, as reported by M. Bilot (*Mélanges scientifiques et litteraires*, 1857, t. ii., p. 80), though I do not know on what authority, Pennet was so completely disgraced as to render worthless all evidence furnished by his career. A walled inclosure was prepared for experiment. It

contained ninety small divisions, in five of which metals had been hidden. Dr. Thouvenel having discovered that wet weather hindered success, the experiment was delayed until after eight dry fine days, and it was then fixed for the following day. During the night which intervened, Pennet climbed by means of a ladder into the inclosure. A suspicious person who was watching the ground removed the ladder, and whatever the divining-rod could show, it was unable to show the prisoner the way out. This adventure, being made public, destroyed the credit of Pennet at Florence. Dr. Thouvenel could not deny the fatal fact, but, with true loyalty to science, declared that Pennet's moral defects had nothing to do with his physical faculty. It is only fair to add that no such passage as this is cited from Dr. Thouvenel's works.

Numerous hydroscopes soon appeared in Italy, and a vigorous discussion of the subject followed. One of the latest celebrated experts of this class was Campetti, who was called to Munich in 1806 for scientific examination. One of the writers of this period, the Abbé Amoretti, himself a member of a family containing many hydroscopes, makes the significant assertion that the sensation experienced by the holder of the divining-rod is one of heat or cold. But the name of Amoretti recalls the fact that he was one of those who revived and continued the discussion of "the magic pendulum."

The earliest mention of this apparatus, according to M. Chevreul, is found in the work of Ammianus Marcellinus, the last of the Latin historians, who died A.D. 390. In an obscure passage (lib. xxix., cap. 1), giving the confession of one of the conspirators against the Emperor of the East, this author describes, in the words of the conspirator, the ceremonies adopted by the band to discover the name of the Emperor's predestined successor. Among these was the use of a ring suspended by a fine thread over a disk, around the edge of which, at equal intervals, were the letters of the alphabet. The ring in its oscillations pointed out successively the letters T, H, E, O: whereupon, without further continuing the inquiry, all perceived that Theodorus was the one designated by destiny.

Father Schott mentions the pendulum in his *Physica curiosa* (1662), already alluded to in this paper.

In the latter part of the eighteenth century, and at the beginning of the nineteenth, several scientific men were attracted to this phenomenon. Albert Fortis (*Mémoires pour servir à l'histoire naturelle et principalement à l'oryctographie de l'Italie et des pays adjacents*, 1802), Prof. Gerboin of Strasburg (*Recherches expérimentales sur un*

nouveau mode de l'action électrique, 1808) and Prof. Ritter of Munich (see his report in the Tübingen *Morgenblatt für gebildete Stände*, No. 26, January 30th, 1807) were among the number, as well as the Abbé Charles Amoretti, librarian at Milan, to whom I have already alluded. As this mention of the pendulum is in the nature of a digression, though (as will appear) not without pertinence to my main argument, I content myself with an abstract from Ritter's article. He says:

"Take a cube of pyrites, native sulphur or any metal. Size and form are indifferent. We may use, for instance, a gold ring. This body is attached to a piece of thread, quarter to half an ell long. This is held pinched between two fingers and suspended vertically, all mechanical movement being hindered. It is best to wet the thread slightly. In this condition, the pendulum is held over or close to a vessel full of water, or over any metal, as a piece of money or a plaque of zinc or copper. The pendulum insensibly assumes elliptical oscillations, which form themselves into a circle, becoming more and more regular. On the north pole of the magnet, the movement is from left to right; over the south pole, from right to left; over copper or silver, as in the former instance; over zinc or water, as in the latter. . . . . Over an orange or an apple, on the side of the stem, the motion is the same as over a south pole; on the opposite side, as over the north pole. The same difference in polarity is shown by the two ends of a fresh egg. It shows itself still more strikingly in the different parts of the human body, the head acting upon the pendulum like zinc, the sole of the foot, like copper; forehead and eyes, north pole; nose and mouth south pole; chin like the forehead; and so on, with all parts. The palm and the back of the hand act in opposite senses. The pendulum will move over every point of the finger, and even over the fourth or ring-finger, but, in that case, in an opposite direction. This finger has also the faculty of arresting or diverting the movement of the pendulum. It needs merely to be placed alone upon the table used in the experiment."

So much for the outline of Ritter's statement. He was at this time occupied with Campetti, above mentioned, and naturally he brought together in his thoughts the divining-rod of Campetti with the pendulum of Fortis (Fortis had experimented with it, and it was often called by his name, in consequence; but his death in 1803 deprived Ritter of his advice and aid in further tests).

Campetti was a young peasant from the borders of the *Lago di Garda* who had seen the performances of Pennet, Dr. Thouvenel's

last *protégé*, and had found himself possessed of similar powers. Not only Ritter, but Schelling and Franz Baader examined him. The opinion expressed by Ritter was that the divining-rod is simply a double pendulum, requiring, to set it in motion, a force greater than those which move the pendulum. Ritter wrote this after consultation with Amoretti and others; and after either he or Amoretti had visited and consulted, at Padua, the great Volta.

But Prof. Gerboin carried his scientific study of the pendulum to a much greater extent. His book contains in 356 octavo pages the records of 253 experiments, and a most elaborate theory of "organo-electric force," in its different qualities, expansive, compressive, passive perturbatory and active perturbatory. The simplest actions of these qualities may be indicated thus—to condense from the professor's somewhat verbose description:

By virtue of the *expansive* quality, which resides most abundantly in the thumb and fore-finger, a pendulum held between these two is caused to describe with its centre of gravity a circle. The *compressive* quality, belonging characteristically to the middle finger, will not permit this motion, or will stop it—as when a highly *compressive* man touches the hand of an *expansive* man, which is holding the swinging pendulum. Contact ceasing, the movement recommences. The *passive perturbatory* is a high degree of the expansive, and the *active perturbatory* is in like manner a powerful *compressive*. The possessor of the former, if while holding a pendulum he is suitably touched by one of the first or second class, will find the pendulum, if at rest, to start backward; and if in motion already, to reverse its motion. The fourth class is, like the second, negative in its action. Persons exercising either the compressive or the active perturbatory quality cannot cause the pendulum to oscillate; they can only counteract or reverse its oscillations in the hands of others.

Considering that the author goes on to formulate the permutations and combinations of these qualities of force, their relations to the different fingers, and to a long list of organic and inorganic bodies, I may be excused from following further his intricate and obscure system. Elaborate as it is, the whole structure is absolutely baseless; and constitutes a capital example of what St. Paul denominated "science, falsely so called." Its vast array of worthless experiments are merely so many ciphers in a row, with a decimal point instead of a unit at the head. When the distinguished chemist Michel Eugène Chevreul (long the chief of the Gobelin tapestry-works, and the author of a well-known book on Color, as well as

other important works) took up the subject in 1812, he was not long in discovering that when the eyes of the operator were blindfolded, so that neither his will nor his thought could consciously or unconsciously affect the movement of the pendulum, the data, arguments and conclusions of Fortis, Amoretti, Ritter and Gerboin, the organo-electric force, with its qualities *expansive, compressive* and *perturbatory;* the south poles and north poles, the classification of the universe thereby;—in short, the entire science, bag and baggage, disappeared!

Gerboin had pronounced the action of the divining-rod to be a case of *passive perturbatory.* Chevreul, as we shall see, put both the rod and the pendulum in a new category. But before proceeding to state his theory, I will devote a word or two to the evidence presented in our own country.

It is safe to say that most of it, like most of the evidence of the past, is open to the suspicion of at least an alloy of deception. Men who make money out of their reputed skill with the divining-rod and who could not make as much money or advertise themselves so widely if they claimed only a high degree of skill as prospectors, will almost inevitably ascribe to the rod what is due to other means of inquiry; will explain away failures, exaggerate successes, and not establish or execute or permit really thorough and sincere experiment. The most distinguished expert in this art on the Pacific coast has been repeatedly made ridiculous by the result of test experiments. On one occasion, as I learn from an eye-witness, who also reported the circumstances to the *Mining and Scientific Press* of San Francisco, this diviner was permitted to inspect a metallurgical laboratory, which always contained a large amount of gold, either in bullion or coin. After this inspection he was brought (blindfold) again into the laboratory, and assured that no coin or bullion had been removed. Under these circumstances he was requested to find the metal with his rod. The coin had all been put in its natural receptacle, the fire-proof safe; and the bullion had been fastened with wire to the under-side of a writing table. The operator found neither of them, though the point of his rod was frequently within an inch of thousands of dollars. He had probably suspected a trick, and he declared that the gold had been removed. When the bandage was again removed from his eyes, and the coin and bullion shown to him, he claimed that his rod had been diverted by the immense amount of treasure in a bank half a block distant! There have also been operators in California claiming to be natural magnets, and not using

the rod; but they are not known to have accomplished any better success. One of these natural magnets was employed to trace a lost vein for a mining company at Grass Valley, the mine of which had been at one time the most productive in California. Under his direction the company cut for many hundred feet, at an expense of $30 to $40 per foot, through tough serpentine rock, and found nothing. Not only are these belts of serpentine at Grass Valley well known to be barren in general, but this particular belt was actually exposed in a cross-section, parallel to this expensive underground cross-cut, only one-eighth of a mile away. The persons most familiar with the mining districts of the West declare that in Grass Valley, and elsewhere, the divining-rod has accomplished nothing of practical value. It is very recently announced by telegraph from Tombstone, Arizona, that a large body of ore has been found at a considerable depth, under a spot indicated by the "hooda-stick" (which, I suppose, is some sort of divining-rod) in the hands of a common workman. I need hardly say that such a discovery proves nothing. It would be of course presumptuous for me, in the absence of information as to persons and circumstances, to criticise this most recent case, but I cannot forbear saying that nothing is more common in experience of mining superintendents than the discovery of ore-bodies by workmen who have carried for a long time the secret knowledge of their existence. Most frequently it occurs when a mine seems to have been exhausted, or at least the superintendent does not know where to look for ore, and finally leases some portion of the ground to miners who, by a good luck that would be surprising if it were not so easily explained, go straightway into a *bonanza*. It is not always, however, the certain knowledge of the existence of an ore-body observed by workmen and kept secret with a view to future profit, which guides these practical explorers. Often it is their great familiarity with the indications of the ground, and sometimes, let me add, the ignorance and pride of the manager himself co-operate with this result, by leading him to pursue some erroneous theory of exploration, and to refuse the advice of practical men. The so-called instinct of Mexican miners for finding ore, exhibited particularly in such irregular formations as those of the quicksilver mines of New Almaden, is, indeed, an unconscious practice of an unwritten science.

The scientific explanation of the movement of the divining-rod was given by M. Chevreul, in a letter to M. Ampère, published in 1833 in the *Revue des Deux Mondes*. This letter contained an account of the experiments made by the writer in 1812, more than twenty years

before, with the pendulum. Finally, in 1853, M. Chevreul, having been appointed by the Academy of Sciences upon a committee to examine a work on the divining-rod, wrote a report on the subject, including the "exploring pendulum" and the then novel wonders of "table-tipping."

This report was published in 1854 under the title *De la Baguette Divinatoire, du Pendule dit Explorateur, et des Tables Tournantes, au Point de Vue de l'Histoire, de la Critique et de la Méthode Expérimentale.* It is worthy of notice that this venerable *savant* is still active at the age of ninety-seven; only the other day, he spoke before the Academy, referring to a paper he had presented to that body, if I remember correctly, seventy years ago!

Chevreul ascribes the movement of the rod, apart from cases of deliberate deception, to minute, unconscious, muscular movements; and these are caused, he thinks, by the imagination or intuitive or unconscious decision or expectation of the operator. An impression that the rod will dip at a certain point, or a wish that it would, or even, in some minds, a fear that it may, do so, are all effective causes of the peculiar muscular movement. Stories describing motions of the rod so violent as to strip the bark from it, in spite of the resistance of the holder, do not disprove the above theory. The position of arms, hands, and fingers usually prescribed for the holding of the rod, as explained in the beginning of this essay, is one in which it is not easy (though not impossible) to produce by conscious effort the peculiar movement referred to. But it is also one in which skilful effort, if employed, may be easily disguised; and finally, it is one which invites muscular cramps, and produces muscular torsions and involuntary movements, not to be resisted successfully without a change of position. Under these circumstances, a man might easily twist the bark from a willow stick, and yet fancy he was trying not to do it.

In concluding this survey of the subject, I shall take a somewhat wider view than M. Chevreul, and my remarks, though based on his theory, should not be received as representing it.

From the mass of testimony, good, bad and indifferent, the following propositions may be safely deduced:

1. The material, consecration, astrological relations and ritual formalities of the rod are entirely irrelevant and indifferent to its efficacy. This disposes at a stroke of nine-tenths of the science which the Middle Ages so laboriously accumulated on the subject.

2. The rod itself is entirely inert, unless in the hands of a human

operator; and according to the declaration of the most famous experts, such as Aymar, Bleton, Amoretti, and many others, and a whole school of diviners who do not use the rod at all, it is merely an index, revealing and magnifying in visible results the peculiar inward sensations of the diviner.

3. The favorite and most convenient form of the rod (λ) is one which promotes involuntary movements and also permits deception.

4. The involuntary minute muscular movements may proceed either from the causes enumerated by Chevreul, or from a truly and purely physical sensation. To this I will presently recur.

5. The uses of the rod for discovering moral qualities, re-locating missing landmarks, tracing stolen property, prophesying the future, or even (as in the 17th century was the case) settling the orthodoxy of theological dogmas, will not now be seriously defended by any one. They belong to charlatanry and superstition.

6. The agency of demons we may also set aside, as a view outgrown if not disproved. The pious Jesuit Gaspard Schott (1662), who held this view, was, as we have seen, shaken in his faith, though not convinced, by testimony showing how often the rod failed to act, or gave unreliable indications. He half admits that if Satan were at the bottom of it, it should work better. As an instrument of divination, it is unworthy of the devil! But it might have been rejoined, that as a means of perplexing and misleading mankind, that distinguished expert could scarcely have improved upon it.

As old Albinus (*Das entlarvte Idol der Wünschelruthe*, 1700) quaintly says:

"Ich achte, dass kein verworrener Ding in der Welt zu finden als das Wünschelruthen-Wesen, denn was Einem recht und tauglich ist, das ist vielen Anderen wieder unrecht und untauglich, dass aus solcher grossen Confusion nicht viel Gutes zu präsumiren ist."

[I ween, that no confoundeder thing is to be found in the world than the divining-rod business; for whatsoever is right and fit according to one, the same is wrong and unfit according to others; until there is no good to be presumed, out of so great confusion.]

7. The application of the rod to the discovery of metals, coal, buried treasure, etc., is shown abundantly to be chimerical. The rules and methods, as well as the asserted performances, of its professors contradict each other; and innumerable failures and exposures have justly covered their pretensions with ridicule.

8. The transparent humbug of locating wells with the rod, to strike oil at depths of from a hundred to thousands of feet, needs no com-

ment. In this case, there are positively no signs by which a given *spot* can be selected. The experience of neighbors may show a certain area to be probably productive; and within that area a certain line may be inferred, sometimes, to be the line of a productive channel. But if a keen observer, having gone so far, professes to select a point on that line, he is simply betting on his luck; and, as carried on in Pennsylvania, the bet is a safe one for the the oil-smeller, who gets a handsome fee if he wins, and loses, in the opposite event, nothing but an hour or two of time.

9. The case is somewhat different with the discovery of springs, and (since ore-deposits always have been and often still are the channels of springs) of ore-deposits. Here we have much stronger and more abundant evidence in favor of the rod; and here, in my judgment, there is a residuum of scientific value, after making all necessary deductions for exaggeration, self-deception and fraud. Keeping in mind that the rod is merely an index to the minute muscular movement, and that this movement may have a mental or a physical cause, let us consider (putting aside at once all cases of deliberate deception) the following facts:

There is undoubtedly a practical science of discovering mineral deposits and springs. The most skilful prospectors can scarcely explain how they decide upon the place where they dig; and yet, though they are by no means always successful, it is certain that they are more successful than the inexperienced. The books, from Agricola down, give rules and signs; but the practical explorer is unacquainted with the books. He has a science of his own, which affects his mind, without conscious reasoning, by the principles of association and memory. He recognizes in a new locality the tokens that he has become accustomed to associate elsewhere with a rich gulch, or an abundance of pay-quartz. Perhaps he never took conscious note of them, yet their recurrence affects his judgment. This practical skill is almost unerring within narrow limits. Under new conditions, it breaks down. Some of the most absurdly foolish gold-mining enterprises I have known, have been set on foot by old California miners, who, returning to their former homes east of the mountains, have said at once of some ravine or hillside, that it was "just the place for gold." In like manner, certain omens and signs from Cornwall have been carried around the world by Cornish miners. But whatever the errors of practical prospectors, the noteworthy point is, that in localities with which they are familiar (or in other localities where the conditions are the same) they come swiftly, surely, and without

conscious reasoning, to impressions and decisions. A decision of this kind would probably, in a man of suitable nervous organization, affect the muscles already constrained by holding a divining-rod, and the minute muscular movement or inward sensation might be unconscious.

The case is still plainer with regard to the discovery of springs. Everybody knows that Indians in our desert West can find water where most white men cannot; and the experienced frontiersman has learned the art from the savages. The conformation of the surface, the tracks of animals, above all, the presence or absence of certain plants, are his guides. In regions where the finding of water within a few feet of the surface is a question of life or death, it becomes a science very rapidly. The location of artesian wells is a different matter. Science will do that in a general way; but science will not determine a difference between one spot and another, ten or twenty feet away, the geological and topographical conditions being alike in both; and the selection of one of two such points as better than the other for a deep well, is purely a piece of imagination or deceit. It must be remembered, however, that the diviner has in such a case an easy task. If possessed of sufficient practical judgment to decide that a certain area or line would probably be suitable for boring, he is pretty sure to be safe in selecting any point of it. But this, it will be seen, is very different from the unconscious skill which points out in the dry *arroyo* the very spot where water will be found in half an hour's digging.

In abundantly watered regions like New England, it is perfectly well-known that the springs follow under or through the soil and above the bed-rock, more or less defined channels. A well may be dug at one point without success, and a subsequent attempt a few yards away may be successful. The superficial signs of these water-courses are often subtle, and they are little studied by the inhabitants in general. It is not necessary that a farmer, who will want to locate a well once in his lifetime, should know the signs of water as a ranchman or *vaquero* must know them. Hence, men who are keen observers (in many instances, finding profit in the business) get impressions, amounting to a local science, of the "lay" of the rocks, the general courses of the springs, the differences in surface vegetation, the earlier or later greenness of grass, the presence of particular grasses and shrubs, the ascent of local vapors at sunrise, the behavior of frosts, in short a hundred minute tokens which betray the presence, even at considerable depth, of a water-channel, and the

point at which it comes nearest to the surface. The unconscious judgment of such an expert may decide upon a given spot over which he walks; and while he could undoubtedly come to this conclusion without having a rod in his hand, I am willing to admit seriously that the rod may help him make up his mind by emphasizing for him his own slightest tendency to a decision. It should be remembered here that even Bleton, the greatest of all the hydroscopists, generally used to go (if permitted) many times over a piece of land before finally locating a well, and often disregarded the first intimation of the rod. In other words, unless he felt sure, every time he crossed a given spot, that it was a good place to dig, he did not rely upon his first sensation or impression. Moreover, neither he nor any other hydroscope has ever accurately divined, except on an occasional lucky guess, either the distance from the surface or the quantity of a subterranean spring. Yet a very large spring, or one very near the surface, appears to have had, usually, a relatively greater influence upon hydroscopes.

This brings me to the final inquiry, whether there may not be, apart from unconscious skill or judgment, a purely physical effect produced by a subterranean spring upon a person walking over it. Electrical theories on this point were only possible in the days when the laws of electricity were little understood. We know now that the earth is a vast conductor, and that the tension of its currents is consequently so low as to be reckoned as the zero of the electricians' scale; hence, that no perceptible electrical current can leave a particular bit of the earth to pass through a human body and return. For this purpose analogies between rock-contacts or fissure-veins and the voltaic pile are inapplicable.

But the effects of moisture and temperature upon the nerves are often striking; and here, I think, is a matter which writers on the divining-rod have generally overlooked. The distance at which animals will "scent water" is very great. Their faculty is supposed to consist in great sensitiveness to temperature and moisture. The quickness with which some people "catch cold" on the slightest exposure to dampness—particularly of the soles of the feet—is also a familiar phenomenon. Now it is curious that among the most puzzling of the well-authenticated accounts of the divining-rod are related instances in which women, unacquainted with its use, and not expecting it to work in their hands, have found it to dip without their conscious help, over spots previously or subsequently shown to contain springs.

Here I would recall the remark of Amoretti, that the sensation of the diviner is one of heat or cold. These two are not easily distinguishable when minute and transient. What we call a chill includes both. Is it not probable that a single unconscious chill may be the physical result to certain sensitive persons, of walking over a spring of water or a belt of rock or soil kept by running water cooler than the adjacent rock or soil, or a spot of surface made by the same cause damper than the surrounding surface? That these causes exist, is beyond doubt. Thermometrical measurements have not been made; but the way in which grass grows and snow lies and frost settles and vapors rise over springs, is due to the temperature and moisture of the ground in such places. Goethe, in one of his novels (*Die Wahlverwandschaften*, I believe), describes a lady as seized with a sudden chill upon a spot where subsequently the outcrop of a coal-bed is discovered. The incident is introduced without attempt at scientific explanation, and apparently to convey to the reader a vivid conception of the lady's extreme delicacy of temperament. I infer from it that such cases were known to the great philosopher, and that he believed such supersensitiveness to be in some way connected with the performances of diviners.

To this then, the rod of Moses, of Jacob, of Mercury, of Circe, of Valentine, of Beausoleil, of Vallemont, of Aymar, of Bleton, of Pennet, of Campetti—even of Mr. Latimer—has come at last. In itself it is nothing. Its claims to virtues derived from Deity, from Satan, from affinities and sympathies, from corpuscular effluvia, from electrical currents, from passive perturbatory qualities of organo-electric force, are hopelessly collapsed and discarded. A whole library of learned rubbish about it, which remains to us, furnishes jargon for charlatans, marvellous tales for fools, and amusement for antiquarians: otherwise it is only fit to constitute part of Mr. Caxton's *History of Human Error*. And the sphere of the divining-rod has shrunk with its authority. In one department after another, it has been found useless. Even in the one application left to it with any show of reason, it is nothing unless held in skilful hands, and whoever has the skill may dispense with the rod. It belongs with "the magic pendulum" and "Planchette," among the toys of children. Or if it be worthy the attention of scientific students, it is the students of psychology and biology, not of geology and hydroscopy and the science of ore-deposits, who can profitably consider it. For us miners and prospectors, the advice holds good which was given us three hundred years ago by the wise Agricola, the father of our pro-

fession, who says the believers in the rod find some veins with it by accident. "*Sed idem multo sæpius perdunt operam, et ut venas invenire possint, nihilominus in fossis agendis defatigantur, quam adversæ partis metallici.*"—"But the same people much more frequently lose their pains, and in order to discover veins have to fatigue themselves with digging, not less than the miners of the opposite school."

As a piece of sorcery, he goes on to say, the virtuous and respectable miner will avoid it; as a piece of science, it is inferior to the study of nature, following the indications of which, the skilful and prudent miner selects a good place for exploration, and "*ibi metallicus agit fossas*"—"there the miner digs"—to which business, rod or no rod, he is bound to come at last.

THE NATURAL COKE OF CHESTERFIELD COUNTY, VA.

BY R. W. RAYMOND, PH.D., NEW YORK CITY.

THE substance known as carbonite, or natural coke, has been several times the subject of comment before the Institute. The most important contribution hitherto made to the discussion is that of Dr. Henry Wurtz, of Hoboken,* who states, upon the strength of a chemical analysis, that carbonite is not a coke, but contains 14.08 per cent. of volatile combustible matter.

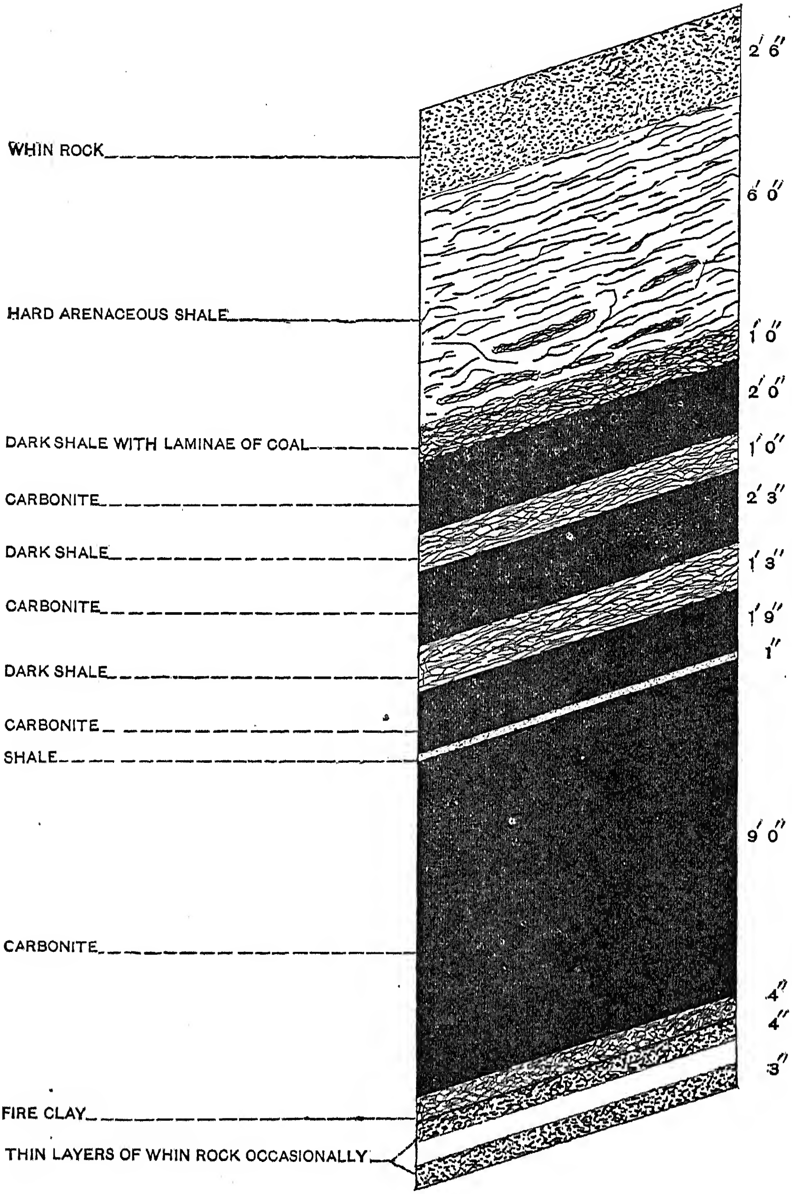
In 1882 a mine was opened upon a carbonite seam, near Midlothian, Chesterfield County, Va., by Messrs. Jewett & Brother, of that place. The seam, which dips westerly at an angle of about 30 degrees, was struck at the depth of 137 feet with a vertical shaft, and followed on the dip 325 feet, at which depth gangways were opened north and south. For these statements (having made no personal examination of the locality), I am indebted to Mr. Albert Blair, of Richmond, and for the following section, to Mr. John Bladon, engineer at the mine. The section was taken in the face of the gangway, February 17th, 1883. It shows an aggregate thickness of 15 feet of "coke," of which about 5 feet were extracted by the system employed last winter.

It is reported that under the "coke" seam there is a thick seam of highly bituminous coal, which has been extensively worked on a neighboring property, a little south of the Jewett colliery, the coal being sold for gas-making.

The carbonite is used for domestic purposes, and is said to burn

* *Transactions*, vol. iii., p. 456.

like anthracite, without smoke or soot, and to be less injurious than anthracite to stoves, etc.



This report, though popular and unscientific in character, is worthy of attention. The difference between anthracite and bitu-

minous coal, in the manner of burning, is one concerning which it seems unlikely that the most careless observer could be mistaken; and if the average carbonite contains, like the sample analyzed by Dr. Wurtz, over 14 per cent. of volatile combustible matter, its behavior in burning is certainly peculiar. This consideration led to the analysis of samples obtained through Mr. Blair from the Jewett mine.

The old view, that carbonite was due to the coking of the original seam by the intrusion of a trap dike (expressed in the address of Major Jed. Hotchkiss before the Society of Arts, at London, in 1873), would be more plausible if the presence of a trap dike large enough to produce this effect, and so situated as to produce it upon a single bed alone, and not upon overlying and underlying beds, could be clearly shown. The existence of such a dike has been disputed; and all that I can say on that point is, that among the samples of the country-rock sent to me from the locality, there was no eruptive rock.

CHEMICAL EXAMINATION OF CARBONITE.

By Dr. T. M. Drown.

The samples of carbonite mentioned above were not uniform in character. The fragments could be readily separated into a dull portion and a lustrous portion. These were examined separately. In general, the analyses confirm the statements of Dr. Wurtz already referred to by Dr. Raymond.

Proximate Analysis.

	Dull portion.	Lustrous portion.
Specific gravity,	1.375	1.350
Loss at 100° C.,	2.00	0.69
Volatile matter,	15.47	11.10
Ash,	3.20 (dark brown)	6.68 (white)
Fixed carbon,	79.33	81.53
	100.00	100.00
Sulphur,	4.08	1.60

The large amount of sulphur present, particularly in the dull portion, suggested an examination to determine the condition in which the sulphur exists in this coal. Advantage was taken of the action of an alkaline solution of bromine to determine the sulphur which is present as pyrites or in other metallic combinations. This

method of analysis was described in full by the writer in the *Transactions* of this Institute, vol. viii., p. 569, and vol. ix., p. 656.

Analyses by the Bromine Method.

	Sulphur by Bromine Solution. (Pyritic Sulphur.)	Sulphur in Residue determined by Eschka's Process. (Organic Sulphur)	Sum of the Preceding.	Total Sulphur by Eschka's Process.
Dull portion, . .	2.48	1.41	3.89	4.08
Lustrous portion,	0.247	1.326	1.573	1.60

The amount of iron in the dull portion is 2.29 per cent., in the lustrous 0.31 per cent. If this iron were present in both cases, as FeS_2, the amount of corresponding sulphur would be 2.62 per cent. and 0.35 per cent. respectively. The dull portion was considerably weathered, and contained a large quantity of sulphates soluble in water, and was not, therefore, as well suited to this investigation as it would have been if the pyrites had not been oxidized.

A mechanical examination was attempted of the lustrous portion to see if it would throw any light on the condition of the sulphur. 102 grams were pulverized so as to pass through a sieve of thirty-five meshes to the linear inch; and this was then sifted through bolting-cloth of ninety-six meshes to the inch. 34 grams, or one-third, was retained by the cloth, and 68 grams, or two-thirds, passed through.

The sulphur was determined in these two portions by Eschka's method, and practically no difference found. The finer portion gave 1.66 per cent. sulphur, and the coarser portion 1.60 per cent.

A portion of the coarser powder was then treated with the Thoulet solution (iodide of mercury in iodide of potassium) of 1.369 specific gravity. 10.21 grams were lighter than the solution, and 5.24 grams were heavier. These two portions were then examined with the following results:

Analyses of the Lustrous Portion Treated with the Thoulet Solution.

	Sulphur by Bromine Solution.	Sulphur in Residue by Eschka's Process.	Sum of the Preceding.	Total, determined by Eschka's Process.	Metallic Iron.
Lighter portion, . .	0.203	1.427	1.630	1.70	0.27
Heavier portion, . .	0.341	1.270	1.611	1.59	0.47

The lustrous portion, owing to its smaller amount of sulphur, was not as well fitted for this examination as the dull portion would have been, but the sample of the latter at my disposal, as already mentioned, was so much oxidized that it was unsuitable.

The above analyses are interesting, as far as they go, in tracing the sulphur which exists in the samples examined, but it would, perhaps, not be fair to draw any inferences from them regarding the amount and condition of the sulphur in carbonite. Larger, and thoroughly average samples, would be required for this purpose.

The foregoing determinations were made by Mr. P. W. Shimer.

A SUGGESTED CURE FOR BLAST-FURNACE CHILLS.

BY HENRY M. HOWE, A.M., M.E., BOSTON, MASS.

THE object of the present paper is to suggest injecting into the hearths of iron blast furnaces, whose temperature has become unduly lowered, some form of fuel whose calorific intensity, under the peculiar conditions existing there, is considerably higher than that of liquid petroleum, the use of this substance for melting out chills having grievously disappointed the high hopes which were at first entertained of it.

A chill being a fall of the temperature below that needed for the complete liquefaction of the slag, which requires, according to Plattner, about 1800° C., one would suppose that the chief thing to be accomplished in curing it would be to raise the temperature in the crucible of the furnace. The most obvious ways of doing this seem to be to raise the temperature of the blast, and to increase the amount of fuel in the crucible itself. Simply increasing the rate at which the blast enters the furnace, if carried beyond a certain point, should lower the temperature in the crucible. The existence of a chill shows that the fuel is arriving too slowly at the tuyeres. If air be introduced so rapidly as to be in excess of that required for the combustion of the fuel, all that excess will simply lower the temperature around the tuyeres, carrying the region of intense heat upwards, and weakening its intensity by increasing its size. Up to a certain point, increasing the rate of introducing the blast will increase practically *pari passu* the rate at which the fuel reaches the tuyeres. But when mechanical obstructions, which so often accompany chills, retard the descent of the fuel, there must be a point beyond which this does not hold good, and beyond which farther

increments in the rate of introducing the blast will not correspondingly increase the rate of descent of the fuel.

Up to a certain point, blowing on a match, a candle, or a fire, will cause it to burn more intensely; beyond that point the more you blow the lower will be your temperature, till finally your fire, your candle, or your match is blown out.

Apparently somewhat the same thing is liable to take place in the crucible of a chilling blast furnace. But one would expect that any chill could be melted out if you could considerably increase the rate at which both the fuel and the blast reach the tuyeres, provided that their combustion yields heat enough to raise its own products to a temperature well above the slag melting-point. This should be the more readily effected if the rate of arrival of the blast and fuel be increased in a higher ratio than the rate of arrival of the ore and flux.

Apparently the liquid petroleum has not in general yielded a temperature far enough above the slag melting-point to produce the desired effect, and I think that a little reflection explains clearly why it has not, and suggests the use of some other forms of fuel. I believe that much at least of the disappointment has been due to the kind of fuel injected, to its high percentage of hydrogen and low calorific intensity; and that a fuel of higher calorific intensity would in many cases have accomplished what the petroleum failed to effect.

In the first place, as the petroleum is injected cold and liquid, a great amount of heat is at once consumed in heating and subsequently in gasifying it. The amount of heat thus consumed is so great that the remainder of the heat generated by the combustion of the petroleum is not sufficient to raise the products of that combustion to the slag melting-point, except in the very small region where they remain unreduced from CO_2 and H_2O to CO and H.

Just how great the total heat of evaporation of ordinary petroleum is I cannot say, but there can be no doubt that it is very considerable. Mr. Joshua Merril, an authority in such matters, informs me that from his prolonged experience, he considers it at least as great as the total heat of evaporation of water at 100° C. Assuming it at this figure, preheated vapor of petroleum should raise the product of its own combustion in the blast furnace to a temperature some 176° C. (307° F.) higher than cold liquid petroleum would.*

* The assumptions on which this and the subsequent statements concerning the temperatures produced by combustion are based, are given in full in Appendix I. The details of the calculations are given in Appendix II.

This seems to be about the lowest value we can assign to the difference between the temperature produced by the combustion of cold liquid petroleum and that produced by preheated petroleum vapor.

Now, although the bituminous coals have calorific powers considerably in excess of those which Dulong's law* would assign them, that of petroleum is much lower than this law would imply.

This may be explained as follows: Dulong's law employs the calorific power of *solid* carbon, but of *gaseous* hydrogen. Now, if we regard the bituminous coals not as strictly solids, but as merely extremely viscid liquids, like the bitumens into which they shade, the calorific power of their carbon should be greater than that of solid carbon, while that of their hydrogen should be less than that of gaseous hydrogen, the difference corresponding roughly in the first case to the latent heat of liquefaction of solid carbon, and in the second to the latent heat of gasification of liquid hydrogen. On this view the ratio of the actual to the theoretical calorific power should increase in the case of liquid and subliquid hydrocarbonaceous fuels with the percentage of carbon they contain; and this is the case, roughly speaking, the actual calorific power being much greater than that calculated in the case of the coals, and much less in that of the petroleums.

If, as I believe, this is the true explanation of the low actual calorific power of liquid petroleum, we may conceive that gasified petroleum might have a calorific power approximating that which Dulong's law would give it, using in that law the calorific power of gaseous carbon, 11,214, instead of 8080, that of solid carbon to which this law was intended to apply. On these suppositions the vaporized petroleum should yield in the blast furnace a temperature nearly 1000° C. (1800° F.) higher than cold liquid petroleum would.

This supposition is undoubtedly extreme, and it seems probable that the temperature attained with our preheated petroleum vapor will be somewhere between that just given and that previously assigned it, on the supposition that the total heat of evaporation of petroleum equals that of water. The temperatures corresponding with these two sets of suppositions are given in lines 1 and 3 in the accompanying table.

The preceding statements suppose that the CO_2 and H_2O produced by the combustion of the petroleum are completely reduced to CO and H within a short distance of the tuyeres. The researches

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* Calorific power $= 8080\ C + 34{,}462\ (H - \frac{O}{8})$.

of Ebelman* show that this reduction took place within 17 inches of the tuyeres in a furnace in normal working. But as in our case the chemical composition of the two fuels (and hence of their products of combustion) is identical, the less complete is this reduction, and the more CO_2 and H_2O remain unreduced, the more will the temperature produced by preheated petroleum vapor exceed that produced by cold liquid petroleum.†

Fuel and Conditions.	Temperature reached by products of combustion.	
	On complete combustion to CO_2 and H_2O.	On subsequent reduction to CO and H.
Preheated petroleum vapor, after Dulong's law, taking calorific power of C at 11,214, ...	3950.° C.	2511.° C.
Cold liquid petroleum, ...	2845.	1561.
Preheated petroleum vapor, assuming its calorific power to exceed that of cold petroleum by its sensible heat above 100° C., plus total heat of evaporation at 100° C, ...	3050.	1737.
Acetylene, ...	3840.	2474.
Fine anthracite blown through tuyeres, ...	3389.	2114.
Incandescent anthracite reaching the tuyeres in the normal way, .	3404.	2182.
Ordinary producer gas, ...	2379.	1265.

* Annales des Mines, third series, vol. xx., p. 407.

† Let H^1 = ht units produced by combustion of preheated petroleum vapor to CO_2 and H_2O.

H^2 = ht units produced by combustion of cold liquid petroleum vapor to CO_2 and H_2O.

H^3 = available ht units after reducing to CO and H, the products of combustion of preheated vapor.

H^4 = available ht units after reducing to CO and H the products of combustion of cold liquid petroleum.

$W = \Sigma$ (wt. $\times$ sp. ht.) of the products of the combustion to CO_2 and H_2O.

$W^1 = \Sigma$ (wt. $\times$ sp. ht.) of the products of combustion reduced to CO and H.

T^1, T^2, T^3, and T^4 = temperatures developed by burning (1) preheated petroleum vapor, (2) cold liquid petroleum to CO_2 and H_2O; and on subsequently reducing to CO and H the products of combustion of (3) preheated petroleum vapor, and (4) cold liquid petroleum.

Now $T^1 = \frac{H^1}{W}$, $T^2 = \frac{H^2}{W}$, $T^3 = \frac{H^3}{W^1}$, $T^4 = \frac{H^4}{W^1}$.

$H^1 - H^2 = H^3 - H^4$:

Hence $T^1 W - T^2 W = T^3 W^1 - T^4 W^1$: or $W (T^1 - T^2) = W^1 (T^3 - T^4)$;

But $W^1 > W$.

Hence $T^1 - T^2 > T^3 - T^4$.—Q. E. D.

Thus, to repeat, if the products of combustion be completely reduced to CO and H, cold liquid petroleum cannot of itself produce a temperature as high as the slag melting-point, even if no heat be lost by radiation and conduction; but preheated gaseous petroleum can raise the products of its partial combustion higher, perhaps only to the slag melting-point, but perhaps much beyond it, according to the calorific power which we assign to it.

Now this difference between the temperatures attainable with liquid and vaporized petroleum may well enable the latter to succeed where the former fails.

It may be objected that in distilling the petroleum we may materially lower the proportion of C to H which enters the furnace, since many of the hydrocarbons which arise from its distillation are split up by heat, yielding portions of solid C, which may remain in the retort. To minimize this separation of C, the petroleum should be very rapidly distilled, and as rapidly withdrawn from the retort. To understand this objection it must be remembered, that in burning the petroleum it is only the combustion of its C to CO that creates a net gain of heat in the crucible of the furnace. The H, though burned at the tuyeres to H_2O, is immediately reduced to H by the surrounding fuel, its reduction abstracting as much heat as was produced by its combustion, so that it really adds no more heat directly to the crucible taken as a whole than so much N would.* Furthermore, by its great specific heat, more than ten times greater than that of any of the other substances in the furnace, it has a powerful effect in dragging down the temperature. It seems clear, therefore, that for the purposes we are considering H is a far less desirable element than C, and that, *cæteris paribus*, the smaller the proportion of H to C in the fuel the better.

But the proportion of H to C in the vapor differs greatly during different stages of the distillation, and, by diverting the vapors which pass over during the early stages when they are richest in H, and blowing into the furnace only those richest in C, we may hope to bring the average proportion of H to C in our petroleum vapor considerably below that which exists in the original petroleum. This would produce a temperature still further in excess of that attainable with cold liquid petroleum than has been already indicated, and perhaps even approximating the excessively high point

* It, however, indirectly contributes to the heat in the crucible. For every portion of H, as well as of C, thus introduced, we have a corresponding portion of combustible gas added to the gases issuing from the throat, which, by its combustion in the hot-blast stoves, adds to the heat of the blast.

reached by the products of combustion of acetylene, given in the fourth line of our table.

The same thing would be accomplished by gasifying and injecting the heavy crude oils produced in refining petroleum, which are much richer in carbon than the original petroleum is. Indeed, even if these oils were introduced cold and liquid, they would produce higher temperatures than liquid petroleum would.

The calorific powers of three of the gaseous hydrocarbons, marsh gas, olefiant gas, and acetylene, have been actually determined. The proportion of the actual to the theoretical calorific power calculated by Dulong's law is by far the greatest in acetylene (the richest in carbon), and much the lowest in marsh gas (the richest in hydrogen). Analogy would lead us to expect correspondingly high actual calorific powers in the other hydrocarbons which are rich in C.

Another consideration points in the same direction. In addition to their needing higher temperatures it is highly probable that these hydrocarbons, rich in C, require a greater amount of heat for their distillation than those rich in H. This means that their latent heat of gasification is greater, and hence that the excess of their calorific power in the gaseous state over that in the liquid state is also greater than in the more easily volatilized compounds rich in H.

The fact that the proportion of the real to the theoretical calorific power is greater in the hydrocarbons rich in C than in those rich in H would further reinforce the already very strong probability that, with the former class of fuels, a much higher temperature will be reached than with the latter, by the products both of complete combustion to CO_2 and H_2O, and of the subsequent reduction to CO and H; and it increases the difference we may expect to find between the temperatures attainable with these two classes of hydrocarbons.

Let us take the case of acetylene, whose behavior analogy leads us to expect would be resembled by that of the hydrocarbons of similar composition. Not only is it very lean in H, having only 7.69 per cent., while crude petroleum has about 15 per cent., olefiant gas 14.3 per cent., and marsh gas 25 per cent., but it is exceedingly stable, parting with its carbon slowly and only at a high heat. Moreover, it has an exceedingly high calorific power. While crude petroleum has actually 85 per cent. of the calorific power which Dulong's law would assign to it, olefiant gas 81.8 per cent., and marsh gas 76.8 per cent. (for the latter two compounds substituting the calorific power of gaseous carbon 11,214 in place of that of solid carbon 8080), acetylene has 92 per cent. and 118 per cent. respectively, as

we assign to the calorific power of C in Dulong's law 11,214 or 8080 units.*

So great is the calorific power of this gas, that it would be capable of raising the products of its complete combustion by air to 3840° C.; and even after being reduced to CO and H by the incandescent fuel in the blast furnace, they should reach a temperature of 2474° C., nearly 700° above the slag melting-point, and nearly 900° C. (1620° F.) above that attainable with cold liquid petroleum. Acetylene is readily produced from petroleum, which, indeed, seems to be its most economical source.

But we may obtain a still lower ratio of H to C by employing another class of fuel. If finely powdered anthracite, coke, or charcoal could be introduced into the crucible in large quantities, it would raise the products of its combustion to a temperature far above that attainable with preheated petroleum vapor of the composition of crude petroleum, and very nearly as high as that which is developed by the combustion of the incandescent fuel which is charged at the tunnel-head and reaches the tuyeres in the normal way. What this latter temperature actually is we do not know. If all the heat were utilized in heating the products of combustion, and if the specific heats of the substances concerned were the same as at ordinary temperatures, we should look for a temperature of about 3404° C. on complete combustion to CO_2, and of 2182° C. on the subsequent reduction to CO, were it not for dissociation.

The experiments of Bell show that the temperature of the slag, which roughly represents the average temperature of the crucible, is far above the melting-point of wrought iron (say 1600° C.), as a bar of that metal inserted in the slag as it ran from the furnace was rapidly melted, collecting in a basin farther on.†

Cailletet found that platinum, whose melting-point is estimated at about 2600° C., melted rapidly at a point about 7 in. in front of the tuyeres.‡

Of the three, anthracite, charcoal, and coke, the former should yield the highest temperature on account of its high calorific power, which is probably considerably above that which Dulong's law would assign it.

One can hardly believe that the mechanical difficulties in the way of introducing large quantities of finely divided fuel are really in-

* Based on Thomsen's determinations, Deut. Chem. Ges. Ber., VI., 1533.

† Journal Iron and Steel Institute, 1871, p. 298.

‡ Traité de Metallurgie, Gruner, p. 466.

superable. If they can be overcome, I can see no reason why this expedient should not enable the iron smelter to obtain a temperature in his crucible sufficient to melt out any chill or overhanging scaffold. One consideration inclines me to believe that such an introduction of extraneous fuel should be even more efficient in melting out chills and scaffolds than a partial breaking of a scaffold itself would be. If a scaffold is partially broken away, allowing the fuel, ore, and flux to fall into the crucible, as they were presumably charged several days before, and, indeed, before the chill occurred, they will simply arrive in the proportion needed for the regular working of the furnace. (Indeed, the very fact of chilling indicates that the fuel may not have been even in sufficiently large proportions for regular working.) That is, the fuel which is precipitated into the hearth will only be in sufficient proportion to heat and melt the ore which enters the hearth with it, and, by making up for the losses by radiation, conduction, and convection, to prevent the temperature from falling. But there will be no excess of fuel to perform the extraordinary work of raising the already lowered temperature, and of heating and melting large masses of chilled and solidified matter. Our extraneous fuel, however, injected directly into the crucible, not being accompanied by any other matter which absorbs heat in being heated and melted except the blast, generates an abundance of heat which is at liberty to raise the lowered temperature around it, and to heat and melt obstructions. All the heat it generates over and above that needed for raising the products of its own combustion above the slag melting-point, is directly available for overcoming the chilled condition of the furnace.

Ordinary producer gas, if made from anthracite, coke, or charcoal, consists almost wholly of N and CO, with a small amount of CO_2. This gas, introduced into the blast furnace, could yield no net gain of heat from chemical action; though its CO would be oxidized to CO_2, it would be immediately reduced to CO again. Hence it is not suitable for introducing into our crucible. If the gas were made from bituminous coal it would be but little better; it would then, indeed, contain a small amount of unoxidized C combined with H, whose combustion to CO would yield some heat, but far from enough to raise to the slag melting-point the immense quantities of inert CO, H, and N accompanying it.

The most beautiful way of suddenly raising the temperature of the crucible would be to increase the proportion of O in the blast. The great amount of N in the blast has a most powerful effect in

dragging down the temperature, forming as it does, the great bulk of the products of combustion. Here, as in so many other operations of metallurgy and industrial chemistry, the discovery of an economical means of producing oxygen, or of even slightly increasing the proportion of oxygen in the air will be an incalculable boon.

To sum up: cold liquid petroleum and ordinary producer-gas, far from having heat to spare, do not generate enough heat to raise the products of their combustion and subsequent reduction to CO and H even as high as the slag melting-point. A somewhat higher temperature should be reached by injecting the crude heavy oils produced at the refineries. Preheated petroleum vapor, on the other hand, especially if the proportion of H it contains be materially diminished in either of the ways indicated, is not open to this objection; and finely divided anthracite, coke, and charcoal would yield a very great excess of heat over and above this requirement.

APPENDIX I.

ASSUMPTIONS MADE IN CALCULATING TEMPERATURES.

In calculating the temperatures given in this article, the following assumptions are made:

(1.) That all the heat generated by combustion, and all the sensible heat existing in the components of combustion, are utilized in raising the temperature of the products of that combustion, and that they neither receive heat from without nor part with heat.

(2.) That dissociation (thermolysis) does not interfere with their rise of temperature.

(3.) That the specific heats of the several substances under consideration remain the same at all temperatures as they are at the ordinary temperature.

(4.) That the pressure of the several gaseous bodies remains constant during and after combustion.

(5.) The following temperatures are assumed for the several substances:

The blast (1100° F.), ...	593° C.
Petroleum vapor, producer-gas, and acetylene (900° F.), .	482° C.
Anthracite injected into the crucible, ...	20° C.
Liquid petroleum, ...	15.5° C.
The incandescent fuel in the furnace which decomposes the CO_2 and H_2O, ...	1500° C.

The trifling effect of the moisture in the air is neglected.

The weight of this incandescent fuel which enters into combustion is so small, that a difference of even 1000° C. in the temperature we

assign it, would imply but a slight alteration in the temperature reached by the products of its combustion.

The fact that none of the first four assumptions is true, does not invalidate the chief deductions which have been above drawn, that the combustion of cold petroleum tends to produce a temperature much below the slag melting-point; that preheated vapor of petroleum will yield a much higher temperature than cold liquid petroleum; that this vapor will yield a still higher temperature if only those portions of it richest in C are used; and that finely divided anthracite, coke, or charcoal, injected, will yield a temperature very nearly as high as that regularly produced by the incandescent fuel in the furnace. Let us take up these assumptions in order.

1st. The temperature T which the products of combustion would reach under this assumption, is a rough measure of the efficiency of the fuel in melting the solid contents of the furnace. It is only the heat generated in excess of that needed to raise their temperature above the slag melting-point T', that is available for raising surrounding objects above T'. If T be lower than T', then in actual working they cannot, no matter in how great quantity they be, raise surrounding objects to T', since heat cannot flow from a colder to a hotter body. This is made clear by considering an imaginary case. Suppose our liquid petroleum to be burnt in a quantity as great as we please in a perfectly non-conducting chamber, whose walls are cold to start with, and from which the products of combustion escape as fast as the components of combustion enter, and from which no heat escapes except the sensible heat contained in the products of combustion. Now these products of combustion would at once reach the temperature T due to assumption 1, were they not surrounded by these cold walls, to which they will radiate part of their heat, the walls becoming heated at their expense. As the walls become hotter the products of combustion will radiate less and less heat to them, and, having so much the more heat left for heating themselves, they will constantly approach the temperature T, as will the walls also. The products of combustion will reach T at the same instant that the walls do, since a condition of their raising themselves to T is that all the heat generated by their combustion is used in raising the temperature of its products, and this cannot be the case as long as the surrounding walls are cooler than the products of combustion themselves, for so long will heat flow from the products of combustion to the walls. But the instant that the walls reach the temperature T, the flow of heat to them from the products of combustion

will cease, since heat does not flow from one body to another at the same temperature (more accurately the flow from each body to the other will be equal, so that neither gains in heat). From this instant the products of combustion escaping from the system in the unit of time carry with them all the heat generated in the same unit of time by an equal weight of components of combustion, being the heat required to raise them to T, so that the system as a whole neither gains nor loses in heat, and consequently remains at constant temperature.*

Hence, combustion, even if it take place in a perfectly non-conducting chamber, cannot raise that chamber above the temperature T which the products of combustion would attain, were all the heat generated by combustion utilized in heating them; and if it cannot do this to a perfectly non-conducting chamber, *a fortiori* it cannot to surrounding bodies which do conduct heat away from it.

In the same way it can be shown that, if the surrounding non-conducting chamber be hotter than T, the temperature of the system will constantly approach T, so that the more combustion takes place in the chamber the faster will the temperature fall toward T. And if the combustion takes place amid conducting bodies hotter than T it will drag their temperature down toward T, and the faster the combustion takes place the faster will the temperature fall toward T.

The temperature T is that to which the combustion tends. The more combustion takes place in the unit of time the more rapidly and more closely will it bring surrounding objects to T, be their initial temperature above or below T.

In our iron blast furnace, if T be below T', as is the case when burning cold petroleum, then if the crucible be also below T, manifestly the combustion of ever so great a quantity of our substance cannot produce the temperature T', as we have seen that even in a non-conducting chamber T is the highest attainable temperature. If T be still below T', and the crucible be above T', then, as in the combustion in the non-conducting chamber hotter than T, the combustion of our substance will drag the temperature down toward T; the more of our substance is burnt the more powerful will be this depressing effect, and it is simply a question of burning enough of it to drag the temperature down below T'.

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* It is here assumed that the combustion completes itself the instant that the components of combustion enter the chamber. The very minute, but still appreciable interval, which elapses between the entrance of the components of the combustions we are considering into the blast furnace, and their chemical union, might slightly, but not materially, alter the resulting temperature.

The temperature T attainable with a given set of components of combustion depends of course on their initial temperature. Thus it is that in the regenerative furnaces, where the components of combustion are preheated, temperatures may actually be attained far above the temperature T attainable under assumption 1 with the components of combustion starting at the ordinary temperature. But preheating the material to be heated or melted by our combustion (*e. g.*, the ore and flux, which are preheated during their descent to the hearth) has precisely the same effect on the temperature that preheating the crucible of the furnace has; our combustion will draw their temperature toward T, heating or cooling them according as they have been preheated to a point below or above T. It is to be remembered that the ore and flux yield no heat to the crucible, for, although they come to it hot, they leave it hotter.

From what has been said, I trust that it is clear that cold petroleum and producer-gas (except in the very limited region where the CO_2 and H_2O, resulting from their combustion, remain unreduced) are powerless in themselves to cause a slag-melting temperature; and if the combustion of the solid fuel in the furnace is raising its own products above the slag melting-point, the introduction of cold petroleum or producer-gas, with an equivalent weight of blast, will depress their temperature, and thus lessen their melting power. For a portion of the excess of heat generated by the combustion of the solid fuel over that needed for raising its own products to the slag melting-point, will now be consumed in raising to that point the products of combustion of our petroleum or producer-gas, leaving just so much the less for the normal duty of heating and melting the solid contents of the furnace. With the other fuels we are considering the reverse is true. The heat which their combustion generates is in excess of that needed for raising its products to the slag melting-point, and that excess is available for heating and melting the solid contents of the furnace. Even if the temperature T to which they tend be below the temperature of the products of combustion of the incandescent solid fuel in the furnace, so that the temperature of the latter be higher than that of the mixed products of combustion of the two fuels, yet these mixed products will have more heat in excess of that needed to raise them to the slag melting-point than have the products of combustion of the solid incandescent fuel alone, and will thus have more heat to spare for raising to that point the solid contents of the furnace.

However, we can readily conceive of several different ways in

which a fuel of even as low a calorific intensity as our cold petroleum can indirectly assist our solid fuel to raise the average temperature above the slag melting-point.

If an excess of blast has been used, the introduction and combustion of petroleum without lessening the blast would have a less powerful effect in dragging down the temperature of the products of combustion of the solid fuel in the furnace, than did the excess of blast which preceded it, and which it would neutralize. It would, at the same time, render the atmosphere of the crucible more strongly reducing, and might carburize and thus lower the melting-point of any wrought iron present. In this case, however, the same effect should be produced by diminishing the amount of blast introduced.

Again, it may well be that while the combustion of the solid fuel is producing in one part of the crucible a temperature well above the slag melting-point T', the remainder of the crucible may be so cold, and the radiation of heat to it from the hotter part of the crucible so rapid, as greatly to limit the region which stands above T'. Now, the introduction and combustion of our cold petroleum in this cold part of the crucible, though unable to raise the temperature of the latter to T', or even to T, may still raise it very greatly, thus diminishing the radiation of heat toward it from the hotter part of the crucible, and thus increasing indirectly the temperature of the latter and enlarging the region whose temperature is above T'.

Again, the chill may be so located that the effect of the very high temperature existing in the extremely limited region where the CO_2 and H_2O, arising from the combustion of the petroleum, remain unreduced, may more than counterbalance the effect of the petroleum in depressing below the slag melting-point the temperature of the crucible taken as a whole.

In whatever way we suppose the cold petroleum to assist in overcoming a chill, it is hardly conceivable that the other fuels recommended in this paper, should not be more efficient than it is.

2d. We know that dissociation does interfere with the rise of temperature from combustion, and, therefore, that the temperatures actually attainable with the several substances we have considered, are liable to be much below what we have calculated. But it is also exceedingly probable that, of two substances, the one whose combustion would yield the higher temperature if dissociation did not intervene, will also actually yield the higher temperature under the influence of dissociation. Hence, while it is by no means unlikely that dissociation may prevent our preheated petroleum vapor from

generating the temperature above ascribed to it, it is extremely improbable that its action will materially affect the relations which the temperatures developed by the combustion of the several substances under consideration bear to each other; so that we may confidently believe that our preheated petroleum vapor will generate a much higher temperature than the cold petroleum, that this temperature will be increased materially by increasing the proportion of C in the vapor, and that our finely divided solid fuel will also generate a much higher temperature, indeed, one approaching that towards which the combustion of the solid fuel in a normally working furnace tends.

It seems very unlikely that dissociation can depress the temperatures attainable with gases similar in composition to acetylene or with powdered solid fuel below the slag melting-point.

3d and 4th. The specific heats of the various substances do alter with elevation of temperature, and the pressure of the products of combustion is necessarily somewhat below that at which the several gaseous bodies enter the crucible. While these facts will slightly alter the actual temperatures attainable, they will not materially affect the relations which the several temperatures here calculated bear to each other, and so will not invalidate the conclusions drawn in this paper.

APPENDIX II.

CALCULATIONS OF TEMPERATURE.

CASE. I.—*Temperature Reached by the Products of Combustion of Preheated Vapor of Petroleum, containing C — 84, H — 14, O — 2, after Dulong's Law,* assuming the Calorific Power of Gaseous Carbon at 11,214.*

A. On complete combustion to CO_2 and H_2O.

Composition of products of combustion:

14 H need the O present $+ \frac{14 \times 16}{2} - 2 =$ . . . 110 O from the air.

84 C need $\frac{84 \times 16 \times 2}{12} =$ . . . . 224 O from air.

Total O required in blast, ...	334 parts.	
Nitrogen corresponding, $334 \times 3.31 =$ . . .	1106	
		1440 parts blast.

Products of combustion:

N, ...	1106
CO_2 84 + 224, ...	308
H_2O 14 + 110 + 2, ...	126

* Calorific power = 8080 C + 34,462 $(H - \frac{O}{8})$.

Heat units present:

100 parts petroleum at 900° F. = 482° C., $100 \times 482 \times 0.46$,	22,172
1440 parts air at 593°, $1440 \times 593 \times 0.238$, ...	203,184
84 parts C burned to CO_2, $84 \times 11{,}214$, ...	941,976
$14 - \frac{2}{8} = 13.75$ parts H burned to H_2O, $13.75 \times 29{,}161 =$	400,964
Total heat units, ...	1,568,296

Temperature:

$$\frac{1{,}568{,}296}{(397 = 126 \times 0.48 + 308 \times 0.216 + 1106 \times 0.244),} = \quad 3{,}950°\ C.$$

B. On subsequent reduction to CO and H.

Products of combustion:

Nitrogen as above, ...	1,106
Hydrogen, ...	14
Carbonic oxide $308\left(1 + \frac{12}{32+12}\right) + 126 \times \frac{12+16}{2+16} =$.	588

Heat units present:

Total heat units on complete combustion as above, . .	1,568,296
Plus heat developed by burning to CO the fuel which reduces the CO_2 and H_2O, $84 + 14 \times \frac{12}{2} = 168$ parts $C \times 2473$, ...	415,464
Plus sensible heat of ditto at 168° C., $168 \times 0.22 \times 1500$, .	55,440
	2,039,200

Less loss on reducing to CO the 84 C originally burnt to CO_2, 84×5607, ...	470,988	
Less loss on reducing the 14 H from H_2O, $14 \times 29{,}161$, ...	408,254	
		879,242
Net heat units available, ...		1,159,958

Temperature:

$$\frac{1{,}159{,}958}{(1106 \times 0.244 + 14 \times 3.4 + 588 \times 0.245 = 462),} = \quad 2{,}511°\ C.$$

CASE II.—*Temperature Reached by Products of Combustion of Cold Liquid Petroleum of same Composition as in Case I.*

A. On complete combustion to CO_2 and H_2O.

Heat units present:

100 parts petroleum at 15.5, $100 \times 15.5 \times 0.46$, ...	713
Heat in blast as in Case I., $1440 \times 593 \times 0.238$, . . .	203,184
Combustion of 100 parts petroleum, $100 \times 10{,}000 - 14 \times 5301$ (because gaseous H_2O is produced), ...	925,786
Total heat units present, ...	1,129,683

Temperature:

$$\frac{1{,}129{,}683}{126 \times .48 + 308 \times .216 + 1106 \times .244} = \quad 2{,}845°\ C.$$

B. On subsequent reduction to CO and H.

Heat units present:

Total heat units on complete combustion as above, . .	1,129,683
Plus additions as in Case I, *B*, ...	470,904
	1,600,587
Less deductions as in Case I, *B*, ...	879,242
Net heat units available, ...	721,345

Temperature:

$$\frac{721,345}{1106 \times .244 + 14 \times 3.4 + 588 \times .245} = \quad 1,561° \text{ C.}$$

CASE III.—*Temperature Reached by Products of Combustion of Preheated Petroleum Vapor, Assumed to be Evaporated at* 100°, *and at that Temperature to have the same Total Heat of Evaporation that Water has.*

A. On complete combustion to CO_2 and H_2O.

Heat units present:

Heat units in case of cold petroleum, Case II., *A*, . .	1,129,683
Plus total heat of evaporation at 100°, 100 (606.5 + 0.305 × 100), ...	63,700
Plus sensible heat at 482° C., in excess of that at 100° C., 100 (482 — 100) × 0.46, ...	17,572
Total heat units present, ...	1,210,955

Temperature:

$$\frac{1,210.955}{397} = \quad 3,050° \text{ C.}$$

B. On subsequent reduction to CO and H.

Total heat units found in Case II., *B*, ...	721,345
Plus additions as in Case III., *A*, 63,700 + 17,572 = .	81,270
Net heat units available, ...	802,617

Temperature:

$$\frac{802,617}{462 \text{ (as in Case I., } B\text{)}} = \quad 1,737° \text{ C.}$$

CASE IV.—*Temperature Reached by the Products of Combustion of Acetylene Preheated to* 482° *C.*

A. On combustion to CO_2 and H_2O.

Composition of products of combustion: Acetylene contains 92.31 C and 7.69 H.

92.31 C require 92 31 × 16 × 2 ÷ 12 = .	246 oxygen.	
7.69 H require 7.69 × 16 ÷ 2 = . . .	62 oxygen.	
Total oxygen needed, . . .	308	
		308 O
308 oxygen will be accompanied by 308 × 3.31 = . .		1,019 N
Total blast required, ...		1,327

The products of combustion will therefore be:

CO_2 92.31 + 246 = ...	338 31 CO_2
H_2O 7.69 + 62 = ...	69.69 H_2O
N, ...	1019.00 N.

Heat units present:

Combustion of 100 parts acetylene, 100 × 11,945, . .	1,194,500
Sensible heat of acetylene, 100 × 482 × 0.46 = . .	22,172
Sensible heat of air, 1327 × 593 × 0 238 = . . .	187,282
	1,403,954
Less deductions for producing gaseous instead of liquid water, 7.69 × 5301, ...	40,765
Total heat units, ...	1,363,189

Temperature:

$$\frac{1,363,189}{1019 \times 0.244 + 338 \times .216 + 69.7 \times .48} = \quad . \quad . \quad . \quad . \quad 3,840^\circ \text{ C}$$

B. On subsequent reduction to CO and H.

Composition of products of combustion:

The total O present will be contained in the resulting CO, which will, therefore, be 308 × (16 + 12) ÷ 16 = . .	539 CO
The initial H will return to its original state, . . .	7.69 H
And, as in Case IV., *A*, above, there will be, . . .	1019 N

Heat development:

Total heat units on complete combustion as above in *A*, .		1,363,189
Plus heat from oxidation of 92.31 + 7.69 × 12 + 2 = 138.5 C of the solid fuel in the furnace, 138.5 × 2473 = . .		342,510
Plus sensible heat of 138.5 parts C, 138.5 × 1500 × 0.22, .		45,705
		1,751,404
Less loss of heat on reducing 92.31 C from CO_2 to CO 92.31 × 5607, ...	517,582	
And on reducing 7.69 H, 7.69 × 29,161, .	224,248	
		741,830
Net heat units available, ...		1,009,574

Temperature:

$$\frac{1,009,574}{539 \times .248 + 7.69 \times 3.4 + 1019 \times .244} = \quad . \quad . \quad . \quad . \quad 2474^\circ \text{ C}$$

CASE V.—*Temperature Reached by Products of Combustion of fine Anthracite Injected through the Tuyeres; the Anthracite supposed to consist of:*

C, ...	90
H, ...	3
O, ...	2
N, ...	1
Water, ...	2
Ash, ...	2
	100

A. Combustion to CO_2 and H_2O.

Composition of products of combustion:

The 90 C needs $90 \times 32 \div 12$,	240 oxygen.
3 H needs $3 \times 8 - 2$,	22 "
Total oxygen needed from blast,	262
Nitrogen corresponding, 262×3.31,	867
Total blast,	1129

The products of combustion will therefore be:

CO_2, $90 + 240$,	330 CO_2
H_2O, $2 + 3 + 2 + 22$,	29 H_2O
N, $867 + 1$,	868 N
Ash,	1 Ash.

Heat units present:

96 parts of anthracite, deducting ash and water, 96×9000,		864,000
Sensible heat of 100 parts anthracite, $100 \times 20 \times .22$,		440
Sensible heat of blast, $1129 \times 593 \times 0.238$,		159,302
		1,023,742
Less deduction for the H_2O produced being gaseous instead of liquid, 3×5301,	15,903	
Less latent heat of evaporation of 2 per cent. water, 2×592.6, evaporated at 20° C.,	1,185	
		17,088
Total heat units present,		1,006,654

Temperature:

$$\frac{1,006,654}{330 \times 0.216 + 29 \times 0.48 + 868 \times .244 + 1 \times 0.2} = \quad 3389° \text{ C}$$

B. On subsequent reduction to CO and H.

Composition of products of combustion:

CO, $330 \times 90 + \frac{29 \times (16 + 12)}{16 + 2} =$	465 CO
H, $29 \times 2 \div 18$,	3.22 H
N as before,	868 N
Ash as before,	1 Ash

Heat units present:

Total heat units on complete combustion as above, Case V., *A*,		1,006,654
Oxidation to CO of $90 + 29 \times 12 \div 18 = 109.3$ C, 109.3×2473,		270,299
Sensible heat of 109.3 C from the solid fuel, $109.3 \times 1500 \times 0.22$,		36,069
		1,313,022
Less loss on reducing 90 C from CO_2 to CO, 90×5607,	504,630	
Loss on reducing 3.22 H from H_2O, $3.22 \times 29,161$,	93,898	
		598,528
Net heat available,		714,494

Temperature:

$$\frac{714{,}494}{465 \times 0.248 + 322 \times 3.4 + 868 \times .244 + 1 \times 0.2} = \quad . \quad . \quad 2114° \text{ C.}$$

CASE VI.—*Temperature Reached by the Products of Combustion of Anthracite charged at the Tunnel-head, and Reaching the Tuyeres in the Normal way.*

A. On complete combustion to CO_2.

Products of combustion:

100 parts C require $\frac{100 \times 16 \times 2}{12}$ = ...	266.67 parts O
266.67 parts O imply 266.67×3.31 = ...	882.67 parts N
And $100 + 266.67$ = ...	366.67 parts CO_2

Heat development:

100 C burning to CO_2, 100×8080 = ...	808,000
Sensible heat of 100 C, $100 \times 1500 \times 0.22$ = ...	33,000
Sensible heat of air, $(883 + 267) \times 593 \times 0.238$ = . .	162,150
Total heat present in the products of combustion, .	1,003,150

Temperature:

$$\frac{1{,}003{,}150}{(367 \times 0.216 + 883 \times 0.244 = 294.72)} = \quad . \quad . \quad . \quad . \quad . \quad 3404° \text{ C.}$$

B. On subsequent reduction to CO.

Products of combustion:

The 100 C in our CO_2 take up another 100 C, making 367 + 100 = ...	467 CO
No new nitrogen is introduced, as before, ...	883 N

Heat development:

Heat development in Case VI., *A*, above, ...	1,003,150
Plus combustion of 100 C to CO, 100×2473 = . . .	247,300
Sensible heat introduced by 100 C, $100 \times 1500 \times 0.22$ = .	33,000
	1,283,450
Less loss from reducing CO_2 previously formed to CO, 100×5607 = ...	560,700
Net heat available, ...	722,750

Temperature:

$$\frac{722{,}750}{(467 \times .248 + 883 \times .244 = 331.3)} = \quad . \quad . \quad . \quad . \quad . \quad 2182° \text{ C.}$$

CASE VII.—*Temperature Reached by Products of Combustion of Ordinary Producer Gas, made from Anthracite, Coke, or Charcoal, by Partial Combustion in a Siemens or similar Producer. Composition assumed at* 32.33 *CO*, 2.03 *CO_2*, 65.64 *N*.

A. On complete combustion to CO_2.

Composition of products of combustion:

To burn the CO to CO_2 will need $32.33 \times 16 \div 12$ = . .	18.47 O
18.47 O will bring in 18.47×3.31 = ...	61.13 N
Total blast needed, ...	79.60

The products of combustion will then be:

CO_2, $32.33 + 2.03 + 18.47$ = ...	52.83
N, $61.13 + 65.64$ = ...	126.77

Heat units present:

Sensible heat of producer gas $(32.33 \times .248 + 2.03 \times .216 + 65.64 \times .244) \times 482 =$	11,795
Sensible heat of air, $79.60 \times 0.238 \times 593 =$	11,223
Combustion of CO, $32.33 \times 2403 =$	77,689
	100,707

Temperature:

$$\frac{100,707}{52.83 \times 0.216 + 126.77 \times 0.244} = \text{ . . . . } 2379^\circ \text{ C.}$$

B. On subsequent reduction to CO.

Products of combustion:

The 52.83 CO_2 take up $52.83 \times 12 \div (12 + 16 \times 2) = 14.41$ C, yielding $52.83 + 14.41 =$	67.24 CO
Nitrogen as before, ...	126.77 N

Heat present:

Heat development found in Case VII., *A*, above, ...	100,707
Plus sensible heat of 14.41 C at 1500, $14.41 \times 1500 \times .22$, .	4,755
Plus heat developed by its oxidation, 14.41×2473, . .	35,636
	141,008
Less loss of heat from decomposing the CO_2 in the products of combustion of Case VII., *A*, 14.41×5607, . . .	80,796
Net available heat, ...	60,212

Temperature:

$$\frac{60,212}{67.24 \times 0.248 + 126.77 \times 0.244} = \text{ . . . . } 1265^\circ \text{ C.}$$

CONSTANTS USED IN THESE CALCULATIONS.

CALORIFIC POWERS.

One part by weight of H to H_2O, the product being gaseous, ...	29,161	
One part by weight of H to H_2O, the product being liquid, $29,161 + 5301$, ...	34,462	
One part solid carbon to CO_2, ...	8,080	
One part gaseous carbon to CO_2, ...	11,214	
One part solid carbon to CO, ...	2,473	
One part gaseous carbon to CO, ...	5,607	
One part carbon from CO to CO_2, ...	5,607	
One part acetylene to H_2O and CO_2, . . .	11,945	the H_2O produced being liquid.
One part liquid petroleum, ...	10,000	
One part anthracite injected, ...	9,000	(Deducting ash and water.)
One part incandescent fuel in furnace to CO_2, .	8,080	
One part incandescent fuel in furnace to CO, .	2,473	

Total heat of evaporation of water, $606.5 + 0.305$ T.*

Latent heat of evaporation of water, $606.5 - 0.695 \text{ T} - .00000033 (\text{T} - 4)^3$.*

* These two formulas are from Rankine's Steam Engine, p. 253.

SPECIFIC HEATS.

Carbonic acid,	0.216
Carbonic oxide,	0.248
Steam,	0.48
Nitrogen,	0.244
Hydrogen,	3.4
Air,	0.238
Ash,	0.2
Carbon, of solid fuel in the furnace,	0.22
Acetylene,	0.46
Vapor of petroleum,	0.46

The last two are mere guesses, but their effect on the temperatures attained is insignificant.

Discussion.

Mr. W. F. Mattes, Scranton, Pennsylvania: There is one point that I would like to call attention to: chills of this character are usually caused by scaffolding. The scaffold prevents a regular descent of fuel to the place in the crucible where it should do its work, and during the prevalence of the scaffold the supply of carbon in the hearth is much diminished, with the result that the proper reducing atmosphere is not maintained. Now it seems to me that the injection of vapor of petroleum into the hearth, in the manner proposed, will fail to supply the one condition that is absolutely essential, namely, an active reducing atmosphere at that point. It might answer to call upon the fuel to carburize the products of the vapor combustion, provided there is sufficient carbon before the tuyeres. But usually that carbon is lacking, and then the carburization will probably occur higher in the furnace, perhaps at the expense of the fuel at the critical point whence the mischief originated, and any good effects are likely to be merely local and not at the right place. If the obstructions at the boshes can be broken, chills in the hearth will rapidly melt away.

Mr. Howe: The notion that the introduction of carbon and hydrogen—be they gaseous, liquid, or solid—into the crucible will weaken the reducing action there, and so increase the tendency to rob the parts above of their carbon, is utterly untenable. It is an increase in the proportion of oxygen introduced, not of such powerful reducing agents as carbon and hydrogen that would weaken the reducing conditions.

Doubtless you should have a reducing atmosphere with your high temperature, but a little reflection shows that we may hope for both.

As the gentleman says, if you keep your petroleum as petroleum you get no heat from it; if you oxidize it to CO_2 and H_2O it will not help your reducing conditions, but if you oxidize it to CO you will increase both your heat and the strength of your reducing conditions. You will not increase the proportion of CO_2 in the crucible unless you increase your blast by an amount which is more than the equivalent of the petroleum injected.

The gentleman seems to agree with me that the chill is due to the lack of fuel at the tuyeres, and he rightly says that, if the obstructions at the boshes can be broken, chills in the hearth will rapidly melt away. This is because fresh fuel will arrive there. Now I simply propose that when you cannot get fuel from above you should force it in from below, and that you should use a fuel of high calorific intensity.

Perhaps he is confused by the idea that it is necessary to have solid carbon at the tuyeres in order to obtain an atmosphere of CO. The gaseous C and H of the petroleum also reduce CO_2 to CO. It is not necessary, as he fears, to call on the solid fuel to perform this reduction. If there should not be enough solid fuel in the hearth to accomplish this, which I consider most unlikely, then the unoxidized portions of the petroleum will reduce the CO_2 and H_2O produced by the complete combustion of the remainder. H and CO cannot coexist at these temperatures.

The obscurity and confusion disappear if we remember that the calorific effect and the effect on the chemical composition of the atmosphere of the furnace caused by introducing petroleum vapor should be parallel with that of introducing incandescent fuel. Indeed we may here regard petroleum vapor simply as a manageable form of carbon, diluted indeed with a little hydrogen, whose presence yields no net gain of heat, but serves to intensify the reducing conditions.

Mr. Mattes: With reference to reducing the products of combustion by unconsumed vapor, it may be noted, first, that as the oxygen supply is continuous with that of the petroleum gas when the latter is in excess, its combustion will yield carbonic oxide and probably steam, but not carbonic acid; and second, that the decomposition of the steam by unconsumed petroleum gas does not produce the same effect as if accomplished by incandescent fuel, because the gas does not carry the surplus temperature of the latter. After the reduction of the steam we will have a mixture of nitrogen, carbonic oxide, and free hydrogen, which is certainly a very desirable atmosphere if obtained in connection with high temperature.

When, as sometimes happens, a scaffold or a fragment slips into the hearth with plugging effect, the obstruction must be directly attacked by the most available means. Under such conditions a powerful blowpipe jet will be a valuable agent, regardless of the composition of the products of combustion. But this treatment should cease when the immediate object is attained, otherwise the trouble at the boshes may be aggravated and the second stage be worse than the first. When once the obstructions are sufficiently broken to bring within reach a body of incandescent fuel, no reagent is so safe and effective as the heated blast.

I had understood Mr. Howe's proposition to be the introduction of a mere jet of petroleum vapor to be oxidized by the blast of the tuyeres. Its introduction in excess is a different matter and, if the heat calculations are correct, removes the chemical objection, while increasing the practical difficulties of its application. One of these difficulties is to gauge correctly the relative percentages of gas and blast; and this will not be met by rapid analyses at the top, because they cannot locate the reactions.

It may be interesting to note in this connection the frequent success that has attended an introduction of steam into the hearth for the purpose of breaking a scaffold. The usual method has been to introduce the steam into the blast-pipe before entering the ovens, but in a recent and very successful case the steam-pipe (1 inch diameter, with $\frac{3}{4}$ inch nozzle) was carried to the nose of a tuyere and opened full to a boiler close at hand, with 115 pounds pressure, for two to three hours at a time. There is reason, however, to believe that in every case where steam has proved efficacious the scaffold-ring had closed rapidly, imprisoning a body of incandescent fuel below sufficient to decompose the steam without undue cooling, thus yielding, still at high temperature, a mixture strongly reducing and very penetrating.

Mr. Howe: I do not know on what ground the gentleman says that petroleum vapor in excess will not produce CO_2 to be immediately reduced to CO: we know that solid fuel, no matter in how great excess, does yield CO_2, which is reduced by that excess.

The difference between the effect of the decomposition of steam by incandescent fuel and by red hot petroleum vapor is much less than might be supposed. If we admit a difference of 500° C. in the temperature of the solid and the gaseous reducing-carbon, that 500° would produce only a difference of some 40° C. in the temperature of the resulting products of combustion, so small a proportion does

the weight of the reducing carbon bear to that of the whole of the products of combustion.

While I do not pretend to say that plenty of practical difficulties would not arise on attempting to carry out such a scheme as I suggest, yet I do not think that one of them will be that which Mr. Mattes has specified—gauging correctly the proportions of gas and blast. While, as I have said, you can have an excess of blast, you cannot have, in the ordinary working of a furnace, an excess of fuel, because the fuel will only descend to the tuyeres as fast as it is burnt there; you cannot make it descend faster. So injecting our petroleum will retard the descent of the solid fuel by consuming a portion of the blast and leaving so much less for the solid fuel. But you cannot get an excess of petroleum over blast into your crucible until the petroleum is in such enormous quantity that it consumes all the blast that enters, leaving none whatever for the solid fuel. To do this would require an amount of petroleum which no one in his senses would dream of injecting.

I can see no difficulty in the way of controlling operations by means of rapid analyses of the atmosphere in the crucible, drawing off samples through holes pierced in its sides.

Mr. R. P. Rothwell, New York: I would ask whether Mr. Howe has considered the use of the mixture of carbonic oxide, known as water-gas, for this purpose. The temperature of combustion is higher, if I remember the figures, than the temperature of combustion of vapor of petroleum, and it may be available here. We find it in similar uses in some other processes requiring high temperature. It is a cheap, economical fuel to procure or manufacture. I have nothing more definite than this mere suggestion to make, as I have not the figures at my command, but I believe its temperature of combustion is very considerably higher than that of petroleum or coal-gas.

In some recent experiments that have been made in Germany with this water-gas they have injected the gas along with the air mixture, either combining it before injection or while it is being injected, and in that way they obtain an extremely high temperature. Whether it would be applicable to the case under consideration I cannot say positively.

Mr. Howe: Water-gas consists mainly of CO and H, with small portions of N and CO_2. On account of its comparative freedom from N its complete combustion with air causes a higher temperature than either C or H. But its introduction into the blast furnace can cause no net gain of heat there, since, though burnt at the tuyeres, it will be

again resolved into its original condition by the solid fuel surrounding it, and the decomposition of the products of its combustion will consume exactly as much heat as was given out on its combustion. The oxidation and subsequent reduction, the generation and absorption of heat, would take place within such a short distance of the tuyeres that probably no useful effect is to be expected from its use. Indeed, as its initial temperature would be lower than that of the crucible itself, it would, in being raised to that temperature, absorb a certain amount of heat, and thereby lower the temperature of the crucible taken as a whole.

Mr. C. Constable, New York: I would suggest that when we speak of a furnace chilling we give the impression that the furnace is likely to go out. It seems to me that chilling is commonly, at the outset, the result of driving the point of combustion up into the furnace, and the word is perhaps a misnomer, since the combustion is still going on. Furnaces have been, of course, banked up for six months at a time and have started off well again, making foundry iron. So that it is not very easy to put out a furnace, to chill it, provided air is excluded. The chilling is rather the apparent cooling of the hearth only, and because the burning-point has been merely driven higher up by an excess of air, as I believe. The hearth, like that of any furnace, is only capable of burning so much fuel per hour, and if an excess of air is blown in it will burn the fuel that is higher up in the furnace, raising the heat on the boshes and rendering the stock sticky. The danger, then, is that the stock may scaffold. If the original causes are not removed the tendency at first to hang and slip becomes aggravated, and a permanent scaffold is formed, which, if bad enough, may put the furnace out, it is true. At this stage Mr. Howe's plan may come in play. But when the first indications of the chilling of the hearth are met by a reduction of the revolutions of the engine (to suit the condition that less fuel is reaching it) and, where possible, by an increase in the heat of the blast, I think many of us have not only found relief, but have reduced the tendency to scaffold and chill. What I would call attention to is that, if taken in the first stages, as suggested, serious scaffolds, such as Mr. Howe is treating of, would seldom occur.

Mr. Howe: Doubtless some scaffolds and chills can be remedied in the way the gentleman advises, but many others cannot. If you are scaffolded so that coal cannot fall to the tuyeres, merely slacking your blast will not bring your coal down to the tuyeres, nor will it raise the local temperature.

If the amount of fuel arriving at the tuyeres in the unit of time is so small that its combustion (even when no excess of air is injected) does not generate enough heat to raise to the slag melting-point the amount of burden which arrives at the tuyeres in the same unit of time and to restore the heat lost by radiation, conduction, and convection during that time, then your furnace must chill and eventually go out unless you increase the rate at which the fuel arrives at the tuyeres, or raise the temperature of the blast, or otherwise increase the amount of heat in the crucible. If you cannot bring more fuel in from above bring it in from below, but gasify it outside your furnace, and do not lower the temperature of your furnace by gasifying your fuel inside it.

THE LINKENBACH BUDDLE.

BY RICHARD P. ROTHWELL, NEW YORK.

Revolving slime-tables with stationary sprays and oscillating brushes have for many years been a favorite apparatus used for working slimes in German dressing-works, often displacing Rittinger tables and the many variations of Cornish buddles. The difficulty of building these tables larger than 5½ meters (17 feet) in diameter, increasing the cost and making them unwieldy, rendered it necessary also to concentrate the slimes in several operations, because the travel over so short a length of hearth would not suffice for close concentration.

A preliminary sizing is effected in a system of spitzkasten. Herr C. Linkenbach, general manager of the Ems Lead and Silver Works, Germany, devised a buddle, in 1878, which has since worked well and found much favor in Germany, and has been in one instance copied here, at Colorado Springs, without any credit having been given to the original inventor. Linkenbach's plan has been to reverse the functions of the table and the washing apparatus of the old German revolving table. He makes the tables stationary and rotates the washing apparatus, thus enabling him to save in power, and, within certain limits, to increase the dimensions of the table, without in any way affecting its durability or materially increasing its cost.

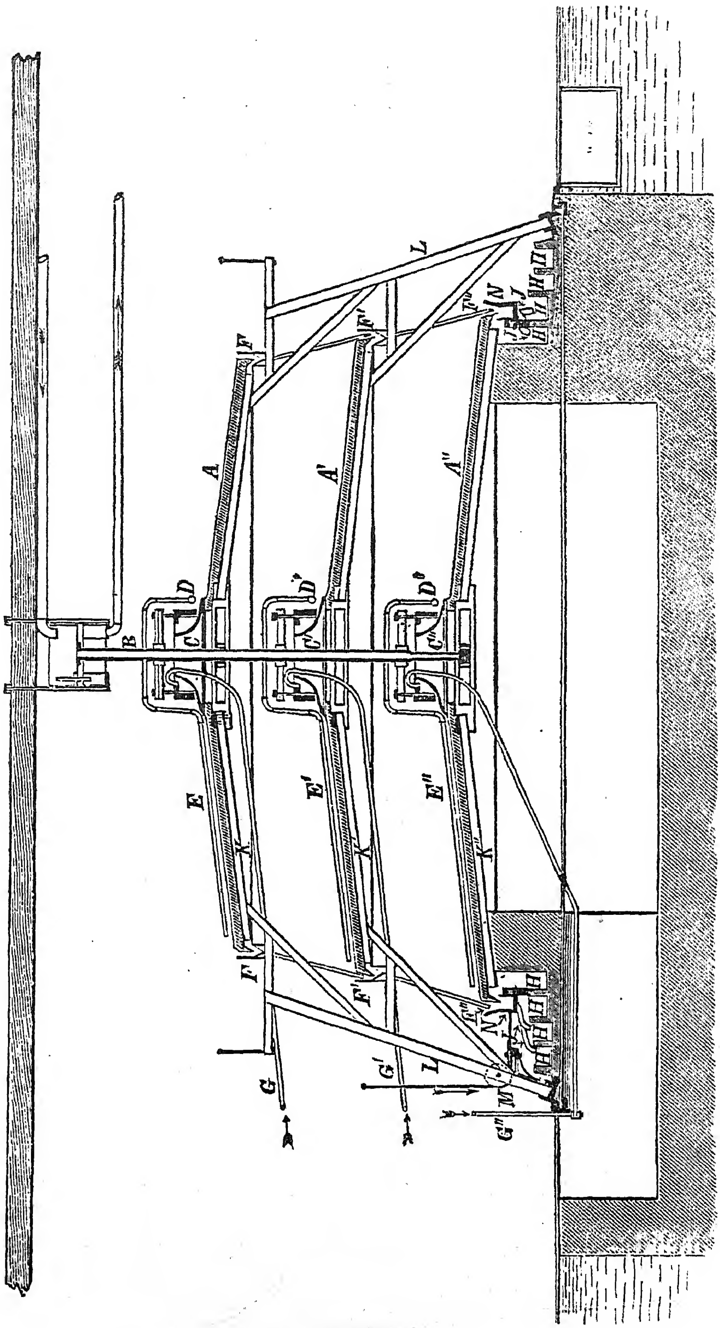
In its earlier form, the buddle was single, and that type is still

desirable when only small quantities of slime are to be worked. In order to secure economy in floor space and cheapen the first cost, by having a single foundation and only one set of rotating mechanisms, Linkenbach now builds the buddles in sets of three, one above the other, as shown in the accompanying drawing. The following figures, giving the cost of a single and a triple buddle at Ems, will fully illustrate this point. In order that these figures may be available under other conditions of cost of labor and materials, I may state that at Ems the cost of labor per shift was 2.80 marks (70 cents); the cost of 1000 kilogs. (1 ton) of wrought-iron, 180 marks ($45), and of cast-iron, 170 marks ($42.50); of 1000 brick, 27 marks ($6.75); and 1000 kilograms cement, 50 marks ($12.50).

	Single.	Triple.
Foundation-work, ...	238.18	296.56
Masonry and cement-work, ...	1075.86	2279.48
Iron-work, ...	2010.07	6451.10
Total marks, . .	3324.11	9027.14
	$831	$2257

It will be noticed that there is very little difference in the cost of foundation; that the cost of masonry is only doubled; while the cost of the iron-work is more than trebled in the triple-hearth buddle. The cost of a single buddle is therefore 3324.11 marks = $831, against 9027 marks = $2257, for one of the triple buddles, not taking into account the saving in floor space and the consequent economy in construction of building, or the saving in driving gear.

I will, therefore, confine myself to a description of the latter form, the principle involved being the same and the connection requiring only a few necessary changes in detail skilfully carried out. As will be seen from the section, there are three stationary tables, the upper one A having a diameter of 6 meters (19.7 feet); the middle one A' of 6.5 meters (21.3 feet); and the lower table A'' of 7 meters (23 feet). The first receives the coarsest grades of the slimes, while the lowest washes the finest sizes; the middle table taking intermediate grades. The tables themselves are made of a skeleton of wrought-iron, the upper surface being cement. The central hollow shaft B rotates, carrying with it the distributors C, C', and C'', the washing-pipes D, D', and D'', the cleaning-jets E, E', and E'', and the rotating catch-gutter F'' of the lowest table, while the catch-gutters F and F' are stationary. The slimes, coming from a separate spitzkasten for each table, are delivered by the pipes G, G', and G''.



THE LINKENBACH BUDDLE.

The action of the buddle is simple. The slimes, flowing continuously over the tables, are first met by a current of water from the washing-pipes *D*, which carries off the middlings, the tailings having flowed off the table before the washing water reaches it. When the spray jets *E* reach the point of the table passed by the washing-pipes, the headings are flooded off the table. The various grades of concentrates are kept separate by the four gutters *H* and the rotating catch-gutter *F''*, by means of pipes *J*, varying in length. The tailings, middlings, and headings from the lower table flow upon the rotating catch-board, which has adjustable compartments for their reception. Those from the other two tables go to stationary circular catch-gutters *F* and *F'*. The bottom of the latter consists of a series of funnels closely placed, the bottoms of which connect with pipes leading to the lower rotating catch-gutters. From the different compartments of the latter, the headings, middlings, and tailings are taken by the pipes to the gutters *H*.

With a single-table buddle, from 5200 to 6600 kilograms (from 5½ to 7 tons) of slimes, weighed dry, have been worked in a ten-hour shift, the percentage of material in the slimes being about 5½ per cent., the quantity of water used being from 90 to 100 liters (from 19 to 22 gallons) per minute, of which two-thirds were used by the washing-troughs and one-third by the spray. The lead headings produced assayed 40 per cent. of lead, further enrichment not being considered desirable, because the foreign matter in the concentrates was hematite and spathic iron ore. The tailings yielded by wet assay from 0.75 to 1 per cent. of lead.

On the triple buddle, slimes containing galena and blende were worked at Ems to the extent of from 6000 to 7000 kilograms (from 6½ to 7½ tons) per table per ten-hour shift. The consumption of water per minute was from 110 to 120 liters, the proportion of water from the troughs and the jets being 2.25 to 1. The galena headings run from 55 to 60 per cent., while the blende concentrates contain from 40 to 42 per cent. of zinc, and the tailings hold by wet assay from 1 to 1.25 per cent. of lead and from 2 to 2½ per cent. of zinc.

Among the great advantages this buddle possesses are the possibility of making and maintaining the table perfectly true, great simplicity of construction, great durability, perfect control of the water and of the degree of concentration, as well as of the number of classes into which the ore is to be made, and economy in space and in first cost.

A COMPARISON OF THE EOZOIC AND LOWER PALÆOZOIC IN SOUTH WALES WITH THEIR APPALACHIAN ANALOGUES.

BY DR. PERSIFOR FRAZER, PHILADELPHIA.

INTRODUCTORY.

THE "author's edition" of the following paper, "subject to revision," was received by him, and copies sent to Professor Geikie and others about two weeks before the date of the meeting at which it was to be read. A telegram, and subsequently a letter (both of which unfortunately arrived too late), apprised the present writer that the Director General objected to certain views ascribed to him as the reverse of those which he really held. These views, however interesting, had no very important bearing on the object of the following notes, which, as must be evident, are devoted to the consideration of the close analogies between the Welsh and American rocks. Without being able, therefore, to account for the circumstance which Professor Geikie has mentioned, it is thought better in the present *revised* edition to omit all allusion to Professor Geikie, or Mr. Peach, or their views, except in this place, where I desire to thank them for their courtesy during the time which I had the pleasure of spending in their society.

It appears sufficiently throughout the body of the paper that the writer had not the slightest intention of entering the controversy, which was about to commence, concerning the proper horizons of the St. David's rocks, for many reasons; and amongst others because he did not feel that a sojourn of a few days in a difficult region, which had been already studied by many of the foremost geologists of England, would warrant him in adding to the literature on the subject. The discussion of the analogies between these rocks and those of the Eastern Appalachians, which he has studied for twelve years, of which eight were spent in the service of the Second Geological Survey of Pennsylvania, was much more to his taste as it was more within his ability, and if he has added anything to the evidence of these analogies, the paper, however imperfect, will not have been written entirely in vain. Right or wrong, he assumes the entire responsibility of what follows.

The writer is indebted to the kindness of Dr. Henry Hicks* for abstracts of the discussions on Professor Geikie's divided paper, at the meetings of the London Geological Society of March 21 and April 11, from which it would appear that neither Professor Geikie nor Mr. Peach regarded the contact between the granite (containing some amphibole) and the sandstone (conglomerate (?)) at that point on the river Allan, figured in the sketch (page 492), as indicating an envelopment of the latter by the former, since no allusion is made to it.

This relation seemed to the writer so clear that he sketched it and had a wood-cut made of it, in spite of the fact that it gave a rude shock to his gradually increasing conviction of the practical parallelism of the rocks of the South Mountain and those of South Wales, by seeming to prove that the granite was of later origin than the clastic rocks which it environed. The writer has probably made a mistake here, though of what nature he is yet ignorant, and it is only fair to say that, while regretting that the error is his, he is gratified to know that this abnormal position of the respective rocks does not exist. It is true that Professor Geikie mentions a very similar case at Ogof Llesing, where "the conglomerate has been torn off and involved in the granite," but this the writer did not see.

Finally, the writer desires to repair an oversight by which he omitted mention of the paper read by Dr. T. Sterry Hunt, before the American Association for the Advancement of Science, September 1, 1879, on "The History of some pre-Cambrian Rocks in America and Europe." This omission, which was caused by his not having seen or heard of the paper before Dr. Hunt placed it in his hands during the meeting of the American Institute of Mining Engineers at Boston (Feb. '83), is the more important, inasmuch as Dr. Hunt claims and establishes with convincing force the parallelism between the orthofelsites, chloritoschists, epidotic quartzes and granitoid rocks of the Eastern United States, and the quartz porphyries, hälleflintas, tuffs, volcanic breccias, and basic lavas of Wales. He says (p. 11), that he "was enabled to satisfy himself of the correctness both of the observations and conclusions of Dr. Hicks, and of the complete parallelism in *stratigraphy* and mineral composition between these pre-Cambrian rocks on the two sides of the Atlantic."

It will be seen in the body of the present writer's paper that the

* The paper itself was received from Professor Geikie, October 24, 1883.

italicised words do not suitably describe the state of facts as they appeared to him, though it was with a feeling of disappointment that he felt himself obliged to draw the conclusion as to relative age mentioned in connection with the sketch on the River Allan. As to the lithological resemblances they are alluded to continually, and in fact form the raison d'être of this paper.

An interesting point brought forward by Dr. Hunt is the occasional absence of the hälleflinta, or orthofelsite group, from its normal position between the Laurentian and Huronian. He instances (p. 8) Western New England and the province of Quebec. The present writer adds to these localities the region of the South Mountain near the Potomac. A few miles north of this latitude or on the Pennsylvania-Maryland State line, successive bands of orthofelsite make up a large fraction of the entire mountain, whereas on the Potomac not a trace of the rocks is to be seen.* Another fact which goes to strengthen the theory of non-conformability of the hälleflintas with the Huronian series, was recently observed in the course of some geological studies in the copper-bearing belt of the South Mountain in Adams and Franklin counties, viz., the repetition several times of the chlorite schists, epidotic quartz and orthofelsite in the same order along a line transverse to the axis of the chain, and the discordance in dip and strike between the first and last of these rocks. The epidotic quartz (which is the real gangue of the native copper) seems to have filled the gap caused by successive faults, which have repeatedly brought down the chloritic series to the plane of the orthofelsite. In the same direction also is the evidence mentioned at the end of Dr. Hunt's essay of Mr. Bailey, who noted a break between his Coldbrook (*orthofelsite*) and Coastal ("typical Huronian") groups.

These prefatory remarks would be incomplete without a reference to the very interesting letters which Dr. Selwyn was kind enough to address to me on the 20th of February and the 17th of March. In the first of these, accompanied by a section on the Vermont and Canada boundary, the strong analogy of the structure on the Susquehanna River to that near the Sutton Mountain anticlinal is perfectly made out, and this of itself proves the same agencies to have been at work over great distances along the strike of these crystalline rocks during their passage from light muds to their present state.

In the second Dr. Selwyn concurs in the expressed views of the

* See on this subject the writer's "Horizon of the South Valley Hills in Pennsylvania." Proc. Am. Phil. Soc., Dec. 15, 1882, p. 512.

similarity of structure between Britain and Eastern America, and points out the necessity of contemporaneous but more or less local volcanic action. The question whether part of the rocks of St. David's are altered Cambrian or pre-Cambrian, which Dr. Selwyn sums up with great clearness and cogency, does not enter into the humble framework of the accompanying notes.

During a recent sojourn in Europe the undersigned spent some days at St. David's, South Wales.

The occasion was one which he hailed with pleasure as offering a rare opportunity for studying those classic rocks—the Cambrian—named to a large extent from their exposures at and near there. But, besides the Cambrian, there were present other series of rocks of the greatest interest to the student of Appalachian geology, not alone from their points of resemblance to other rocks met with frequently on the Atlantic border of the United States, but from the similar relations which in most cases they seemed to bear to the measures in contact with them.

General Remarks on the Geology of Wales.

It will be noticed in the geological map of England and Wales that the lower half of the Lower Palæozoic (primary of the English geologists), or the series of beds from the Lingula flags to the top of the lower Llandovery rocks, are largely represented in the latter principality, of which they form the greater part. From Point Carmel and Holyhead to St. David's Head they form an irregular crescent-shaped area, broadest at its mean latitude (where it measures from twenty to thirty miles), and stretching out its prongs towards the west. Back of this, like the old moon with the new moon, is an additional area of Cambrian, also roughly crescent-shaped, and thickest in its middle part.

Both horns of this rude crescent are broken up into small areas of rocks belonging to a great variety of systems, the southern being that to which it is intended to devote a few remarks. In reaching St. David's from London, on the Great Western Railway, one passes from the Carboniferous and Devonian of Glamorganshire at the river Towy, and entering Caermarthenshire at the town of the same name, is at once upon the Lower Palæozoic, which reaches thence west and north with few interruptions for a considerable distance.

Roch's Castle.

From Haverfordwest one proceeds by wagon six miles northwest over the Lingula and Llandeilo series to Roch's Castle, which is built near the point of a mass of rocks, of which the horizontal boundaries suggest a rude resemblance to the head of a dart pointing a little south of west; the distance from the apex to the extremity of each barb being from three to four miles.

These rocks appeared to be known as various forms of "quartzite, together with feldspathic masses." The planes of fracture are too numerous and indeterminate for the writer to be certain which if any are the bed planes. The planes dipping to the northwest at an angle of 60° seemed to the writer, perhaps, the least satisfactorily defined of three sets, one of the latter being nearly horizontal and the other nearly vertical to the ± N. E.

The locality is nearly surrounded by an area of Llandeilo flags containing some fossils.

The flags themselves resembled more nearly what the author has often designated as argillaceous shale, and, in specimens where the decomposition into clay had proceeded very far, there was almost invariably the same disposition to split into prisms of unequally large pairs of parallel planes, no two of which pairs were perpendicular to each other, which gives the fragments a remote resemblance to some of the numerous varieties of triclinic crystals. In the specimens examined by the writer the absence of grit was one characteristic, as was also the dark buff or buckskin color of the thin laminæ.

Like similar argillaceous shales and slates near the town of York, Pennsylvania, and elsewhere in America, the slabs split up into almost any desired degree of thinness; while over the flat surfaces there appeared sometimes a delicate dendritic tracery of raised filaments of sandy clay, more loosely aggregated than the rest, and at others, radial ribs arranged like those so often seen in the fresh conchoidal fracture of unweathered dolerite, and frequently in that of the fracture (not cleavage) of hard altered slates.

But the rock on which the castle is built, on nearer inspection, is not a quartzite proper, though many fragments, from their hardness and planes of fracture, somewhat resemble this rock. It is a siliceous, greenish rock, showing everywhere included crystals of more or less definite outline, generally about the size of a buckshot, and containing a whitish or yellowish feldspar.

The resemblance of this rock to the "jaspers" of Rogers, of which Dr. T. Sterry Hunt was the first to point out the real character, is striking. In the porphyry of Roch's Castle the feldspar is oftener yellowish-green than in the orthofelsite porphyries of the South Mountain and of the Eastern United States, but this applies only in a general way, as there is much of the Welsh orthofelsite which shows flesh-colored feldspar, and much of that of the South Mountain which exhibits green and other colors.*

Portions of this porphyry were very much decayed, and the feldspar crystals, of a dull-whitish color, seemed to form a very large proportion (perhaps 25 to 30 per cent.) of the entire mass. In others the color was a very light pinkish-blue, and the surfaces of fractures were earthy. In others again, the pulp of feldspar and quartz-powder was so fine as to show little trace of grit. This variety of the rock split into thin slaty tablets, of which the small projecting nodules rapidly took a polish from the least rubbing against foreign substances, and exhibited a waxy lustre. Many small fragments of biotite and occasional specks of hornblende were imbedded in the rock. The color of this variety was very generally faintly pinkish. The lamination and flaggy structure, when it was apparent, seemed to be entirely due to the arrangement of the cleavage surfaces of numbers of the small crystals in the same plane, because a large part of the rocks defied all attempts to define sedimentary structure. Similar exhibitions of orthofelsite are found in quantity on the eastern slope of the South Mountain in Pennsylvania, from Dillsburg to Monterey. In the latter region, however, the beds, which make up with them the greater part of the mountain, either resting against them discordantly, or separated from them by a greater or less thickness of epidotic quartz, are typical chlorite schists; whereas these are Llandeilo flags. This junction, too, in the South Mountain is characterized for a part of its extent by an horizon of native copper, of which no trace was observed by the writer near St. David's.

About two hundred yards northwest of Roch's Castle the Llandeilo flags dip S. 10° E. — 70°, while just to the east of this ex-

* A specimen of felsite taken from a large transported boulder at the Falls of Inversnaid, in Dumbartonshire, Scotland (a different kind of rock altogether), is largely pinkish or light-red, of conchoidal fracture in large fragments, and contains imbedded feldspar crystals of 1 or 2 mm., on the side of which the flat surfaces show in numerous lustrous points throughout the mass. It is numbered 5 in the collection herewith submitted.

posure is the upper edge of the slender point of intrusive porphyritic felsite, on the lower edge of which the Castle is built.

The road from Roch's Castle passes over a strip of carboniferous measures, which forms the extreme eastern coast of St. Bride's Bay, and after passing for half a mile or so along the shingle, where a high storm-beach has been raised by the waves, it leads off to the north over the Cambrian, and turns to the west along the north shore of St. Bride's Bay towards St. David's.

St. David's.

The little town of St. David's stands partly on a belt of greenish granite* (or heavy-bedded gneiss?), containing some hornblende, and partly on the beds which have been referred to at Roch's Castle. The former fill a belt of which the northwest edge passes through the town in a northeasterly direction, a short distance from the monastery and palace.

But to the west and to the north of these beds, and forming the other boundary of the Lower Palæozoic measures, masses of greenstones are indicated on the map, which appear as an irregular fringe on the north coast of the headland, but of which the direction conforms to that of the felsites, and both establish a gently increasing easting in the strike, making rounded curves, familiar to those who have seen an orographic map of either the Eastern or Western United States.

In the little harbor of Porth Teli, which lies in the lower part of the bight of Whitesand Bay, between St. David's Head and Point St. John, and about one and a half miles west by north of the town of St. David's, there occurs a thick series of greenish, arenaceous beds, showing numerous streaks of chlorite, which dip ± northwest ± 50°. They appear, from the map, to belong to an area of Cambrian rocks, occupying nearly a square mile on the coast, at and behind Point St. John. These rocks are of very great interest, because they are unmistakably hydromica schists of light greenish or grayish color, very finely laminated, and resembling the rocks of parts of the South Valley Hill, and of parts of Fulton and Manor townships on the Susquehanna River. They have the greasy feel and the feebly glinting surfaces which are typical of those schists formed from minute particles of the margarodite section of micas.

* See microscopic examination of specimens 15 and 19.

Similar schists, which (according to the writer's theory of structure, based on the study of Southeast Pennsylvania) are associated with distinctively chlorite schists, are in contact with the orthofelsite of the South Mountain, in Adams and York counties, Pennsylvania. Very similar schists may also be met (though in this case without the presence of the orthofelsite), in the Chestnut Hill ore banks, just north of the town of Columbia, on the lower Susquehanna, and in the Grubb ore bank, Hellam Township, York County.

Part of these rocks in Porth Teli are very hard, and resemble some of the greenish grits on the left bank of the Susquehanna, near the Maryland line.

To the north of the cove (Porth Teli), and forming its northern headland (St. David's Head), the color of the rocks is greener, and their character is given as *greenstones* on the geological maps, but climbing along the base of the abrupt precipice forming the southern half of the cove, one passes, in ascending order, first, a series of reddish, and then of yellowish-green hydro-mica schists, dipping, like all the measures between here and St. David's Village, about north 25° west ± 60°.

These beds on their exposed surfaces become more and more distinct from each other in color, as their disintegration proceeds, and it is impossible to overlook the analogies which even these physical features present to the variegated clays, chiefly red, and white, and pink, which border the bases of the South Mountain, both on the east and in the Cumberland Valley, in Pennsylvania.

Another paragenesis, strikingly analogous to that in the South Mountain, is found at Trelethyn, about one mile west by north of St. David's, near one of the largest bands which are colored as "greenstone" on the geological map. Here is a hard, siliceous, greenish rock, with interstitial spaces filled with milk quartz and epidote, the latter in large excess. This rock, as is the case very frequently in Pennsylvania, forms low ridges in the midst of the softer chloritic schists and orthofelsites, with which it is almost always closely associated.

More detailed descriptions of such an occurrence will be found in the writer's reports on the South Mountain region, in the volumes of the *Second Geological Survey of Pennsylvania.* The association here in Pencarman, Pembrokeshire, is very like that in Southwestern Adams County, Pennsylvania. In the latter case, it frequently marks the horizons of copper-bearing rocks.

About one-third of a mile southwest of the village of St. David's,

near the ruins of the old palace and abbey, on the road to Trelethyn, the rocks (feldspathic schists) dip ± north ± 50° (magnetic). Purplish fragments very much resembling orthofelsite in color and general appearance, strew the road.

Within the area above referred to as Pencarman, and consisting nearly exclusively of Cambrian rocks, there occur, nevertheless, small patches of igneous rocks, most of them of very limited area, and close to the coast.

Some of these rocks were of the highest interest to the writer, because they resembled others along the lower Susquehanna, which have perplexed him very much, and the point of view from which some geologists regard them suggested to his mind an entirely new hypothesis as to their relations with the neighboring strata.

One of these was at Rhosson, and about five hundred yards from the sea. The rock is a compact and siliceous mass of pale pinkish color, in which small, greenish minerals are imbedded. While it is very compact, traces of its fine lamination are plainly visible, in the ragged, leaf-like ends of hand specimens, and the greater development of large surfaces in one general plane. Its cleavage, too, is roughly along these planes. It lies in a very low ridge, which lifts itself a yard or two above the general level of the ground, and extends a few hundred yards in length. The view taken of its lamination would agree pretty well with the dip of the measures in which it is intercalated, so that nothing (if it be not its lithological character) would suggest an igneous origin. The rock has been called a "porphyritic ash bed," and has been supposed to have been blown out of a vent in the Cambrian measures, and afterwards rudely bedded along with more or less small fragments of orthofelsite, which were mechanically mixed with it from the edges of the strata which the "blow" traversed.

Still further to the southward of east, across the belt of Lower Palæozoic measures, and about a mile west by south of St. David's, at a place called Clegyr Foig, there is also a similar ridge running to the eastward of a marsh and pond. The rock of which it is composed resembles greatly the hard green siliceous rock which occurs near Williamson's Point, on the left bank of the lower Susquehanna, and near the Maryland line. In front (*i. e.* northwest) of this is a thin layer of purplish rock, with whitish, generally more or less decayed, included crystals, closely analogous in its shades and varieties to the orthophyre and orthofelsite porphyry, of the reports lettered C to C_3 of the Second Geological Survey of Pennsylvania.

In front of this again (northwest) is a re-made rock, containing fragments of orthofelsite, and dipping, in a cut of which the direction is southwest, ± north 35° west ± 50°.

A specimen from the hummock back of Clegyr Foig, which it was thought Dr. Hicks considered sedimentary, is a compact siliceous rock, breaking into angles and points, with a tendency to those curved surfaces which distinguish the lavas and basalts. Its color is greenish, its specific gravity and hardness rather high. It resembles, very much, certain rocks which occur in the schists of the Susquehanna, in Lancaster and York counties, Pennsylvania.

The rock composing the ridge which borders the bog is of a very different character. Many specimens are in color not unlike the dull varieties of eklogite, and contain clinoclastic feldspar, pyroxene, and some epidote. Its specific gravity and hardness are about medium, and the mean magnitude of the grains which compose it, though flattened, will average, perhaps, the area of a small pea. It seems to be a re-made rock, including within itself, fragments of orthofelsite, which would fix its origin as later than the latter.

West of the bog, and of the orthofelsite, to the east of it, is the low ridge of hard porphyritic ash rock. Lying on this, to the northwest, is another hummock of orthofelsite. The last elevation, northwest or towards the ocean, in the promontory next south of St. David's Head (Point St. John), is a compact greenish, orthofelsite porphyry, containing many spangles of a ferruginous hydromica schist (the basis of those "variegated" or "paint clays"), everywhere seen where these members of the Eozoic and Lower Palæozoic measures are subject to decay. The southern end of this last hummock is again composed of ash-beds, with flakes of imbedded orthofelsite.

At the foot of this hill, and forming the last rock visible between the mainland and the sea, is a compact mass of porphyritic ash, including fragments of orthofelsite porphyry.

On a small promontory on the mainland, opposite the northeast end of Ramsay's Island (which, itself, is the westernmost point of Great Britain, north of Cornwall), a purplish red sandstone appears interbedded with "porphyritic ash-beds." At this point there appears to be a deflection of the measures more or less, as the strike is slightly different from that of the beds which form the mainland.

Very near the same belt, and on the west headland of St. Bride's Bay, about a mile south of the last-mentioned locality, and ± 3

miles southwest of St. David's, is found a true hälleflinta. This rock, which is practically a synonym of felstone, petrosilex, werneryte, or felsite schist (felsitschiefer), was thought by v. Cotta to be almost always found in parallel bedding with granulite and gneiss, and he has signalized the frequency with which they occur together "among the Lower Palæozoic strata of the British Isles."*

The specimens from the locality just mentioned, or Penmaenmelyn, differ from those mentioned on Pencarman, in being of darker greenish color, more compact with lamination, thicker and smoother surfaces, and in showing a banded structure not visible in the former. They consist of a very hard orthose mass which, it has been suggested, is formed of the fine dust of feldspathic lavas.

Leaving the coast line for a short time, in order to finish the examination of the rocks to the north before proceeding south, we find a very interesting series in or near the town of St. David's. Immediately south of west of the outskirts are the interesting ruins of the old abbey, the site of the present cathedral. Here are visible one or more zones of light bluish-colored compact and crystalline beds, which contain numerous fragments of the Cambrian rocks. The locality whence the specimen of these rocks was obtained was about one hundred yards west of St. David's Cathedral.

Although a whitish crust forms on the exposed surfaces of this rock very rapidly, it is generally firm and unweathered a short distance from the surface. Some dark quartz and a very few spangles of silvery mica are the only constituents of the rock, except the feldspathic mass which forms its base.

Near the tower of St. David's occurs a compact mass of mainly greenish color consisting of quartz and feldspar principally. A granitoid rock on the Allan River shows a quite perceptible pinkish tint in the feldspar, with nodules of quartz and hornblende, and occasional bands of the latter mineral. Its general color is light, and it resists weathering well. The strike of the edge of this granite appears to conform generally to the strike of the bedded rocks adjacent.

From what has been said of the prevalence of a northwest dip between St. David's and the sea, it will be apparent that this horizon is the lowest which has been described in its vicinity, and that, if it may be assumed that the appearances are not deceptive, the or-

* Rocks classified and described by Bernhard von Cotta. English edition by Philip Henry Lawrence, Longmans, Green & Co., 1866, p. 220.

thofelsite beds of Clegyr Foig and Treletlyn are superior to those near the town. Still a band of schists, colored on the map as Cambrian measures, intervenes between the two points, and the true superposition must depend upon the determination of the relations between these two series.

Dr. Hicks, at first, considered the felsites in immediate contact with the lowest rocks a part of the latter, but was induced to separate them later from the underlying "Dimetian" and the overlying "Pebidian" beds.* The granitoid rock, near the town of St. David's, represents a part of this Dimetian series (which, however, the writer expected to find composed of rocks more gneissoid than this in character, from the descriptions which Dr. Hicks has given). This locality, near St. David's, and another, which lies to the south, and is to be described presently, were, therefore, carefully observed, but no trace of schistosity or lamination could be detected. The rough, uneven planes of the rock were observed to assume all possible directions of inclination.

It is a very important point in the proper understanding of the structure here, and its analogy with the Appalachian phenomena, to determine whether the band of schists which intervene between the two belts of intrusive (?) beds be really Cambrian, or whether they may not correspond with the horizon, to which Dr. Hunt and others, including the writer, have supposed that the enormous masses of crystalline schists, which stretch from Vermont to Georgia, belong. On this point the undersigned feels unwilling to express an opinion without obtaining more information and experience of this terrain. It is certain that if they be in reality Cambrian, there are great difficulties in the way of considering the orthofelsite beds to the northwest as forming a part of the Huronian or pre-Huronian, without assuming one or more faults.

The writer repeats that the outcrop of crystalline rock, which has been before referred to as granitoid, and which passes through St. David's, was closely examined in numerous outcrops for signs of lamination, but none such were apparent. The rock, it is true, is cleft by numerous planes, which are filled with serpentinous matter, and which dip in various directions, but no indications of schistosity or gneissoid character were observed. The conclusion seemed inevitable from the lithological character of the mass alone in and near St. David's, that it was a macro-crystalline, intrusive (?) rock. The relation which it bore to the rocks in juxtaposition to it, appeared

* See abstract of his researches at the end of this paper.

more clearly from observations further south, which are shortly to be referred to.

The Allan River (or creek, as it would be called in this country) heads up a short distance to the north of St. David's, and, passing through the village with a slightly southwesterly direction, empties into St. Bride's Bay, about $1\frac{1}{2}$ to 2 miles from it. The first part of its southwestwardly course is given to it by the contact between the granitoid rocks and those colored as altered Cambrian on the geological map. This it follows for some distance below St. David's; but it makes a sharp bend to the southeast, and having traversed the granite near its narrowest point, again seeks the lower junction line between this latter rock and the Cambrian measures before emptying into the bay at Porth Clais.

At the lower mill, on the river Allan, and near the limekilns there, a dike of diabase, 25 inches broad, breaks through the granite, striking about N. 10° W. (magnetic). It is divided across perpendicular to the contact planes of the latter by many planes of cleavage.

Close to this is another thinner dike, dipping about E. 10° S.—75°, and divided into fine prisms, like the Williamson's Point trap.

This is a very interesting locality for studying the structure, and seemed to throw much light on the mooted questions connected with the age of this granite. Thus, on the right bank of the stream and close alongside of a deserted hut, a contact occurs between the Cambrian and a rock which was thought to be the continuation of the St. David's granite or Dimetian. Of this the accompanying cut is a rough representation. C represents the Cambrian strata and S, the granite in the right foreground.

The observer is looking southeast and in the direction of the flow of the stream. In the distance beyond a massive but broken dam situated in the narrow gorge on the left, the water of the Allan finds its way into St. Bride's Bay. The limekilns referred to are situated on the left-hand side of the picture just out of view. The line of contact between the granite and the Cambrian measures crosses the stream in the foreground.

It will be seen from this sketch that the granite appears to cut into and nearly isolate a mass of the Cambrian rocks, which latter it would seem are, therefore, older than itself. The writer believed these Cambrian rocks to be the same that can be followed continuously for about seven miles to the northeast, and to be separated from St. David's only by this granite, which he took to be the termination near the sea border of the belt passing through St. David's.

The conclusion seemed unavoidable, therefore, that the *whole* of the granite mass, of which a part forms the foundation of Southeastern St. David's, is younger than the rocks which lie to the southeast of it.

The contact plane of the granite may be seen on both sides of the stream. The rocks on the east (left) bank of the creek are greenish, and, like diabases, with tendency to conchoidal fracture and radial grooving. On the west (right) bank is the contact, figured in the cut.

There are apparently some evidences of fusion on the contact plane between the granite and the adjacent beds.

View on River Allan, near Mouth, looking S.E.

The diabase referred to as penetrating the granite near this locality is a heavy, dark green compact rock, showing, when it is fractured, strong traces of cleavage planes, and white where the siliceous rock is shattered or reduced to powder like unannealed glass. It contains crystals, somewhat sparsely, it is true, yet sufficiently to form a subordinate characteristic of the rock, because of their well-defined form and their isolation. Magnetite occurs in small grains, and a very perfect garnet with a rhomb of 10 to 15 mm. in length was observed.

The granite which skirts the road and stream in contact with the Cambrian sandstones near the lower mill of the River Allan ex-

hibits a slight rosy tinge, which suggests that part of the feldspar is a true orthoclase. The hornblende is scattered through the rock in small patches, or occurs occasionally in masses the size of a sixpence in area. The rock is hard, compact, and well crystallized, and does not resemble a sedimentary rock.

The "Cambrian sandstones" (if they ever were such), so altered as to become in places veritable "metadolerytes," are hard and vitreous, of pale sea-green color, and though their conchoidal fracture is subordinate, they exhibit the characteristic of arborescent radial systems of the rock material slightly raised above the general surface. The surfaces of fracture are quite irregular, and are veined with white or grayish-white feldspar, which seems to present itself in a netlike form around the pyroxenic mineral, which forms one of its principal constituents.

A specimen answering the above description was taken on the east (left) bank of the River Allan, and about 20 feet south of the contact.

Near Porth Clais on the Allan River and not far from the lower dam is a small vein of trap. This trap is green and breaks into prisms like that of Williamson's Point, Lower Susquehanna. It passes through the Cambrian beds in a narrow thread. Some of the fragments are bent and splintered at the ends like rotten wood. It is highly basic, and is just such as one would expect in the rocks with which it is associated. It is probably more recent than the larger dikes which have been heretofore mentioned, as a very similar material was observed cutting the larger dikes of diabase first described.

The Cambrian red sandstones lie above the green sandstones of the same age, and these latter above the conglomerate beds, which are found on the parts of the coast of St. Bride's Bay adjacent to the mouth of the River Allan. The red sandstones are generally of a dark purple hue, and contain small spangles of mica and other accessory minerals imbedded in them. When viewed in mass at a distance they are in color not unlike the Galisteo beds (New Mexico) of Dr. Hayden, but there are also Old Red and New Red measures, which very closely resemble them.

Dr. Hicks is said to have found in these red and green sandstones, near the mouth of the Allan River, the following fossils:

Paradoxides Harknessi,
Conocoryphe Lyelli,
Lingula primæva.

The sandstones at the mouth of the Allan which contained the above three species are reddish, and are nearly on edge.

The ruins of the Nun's Chapel are situated about a mile due south of St. David's, and about $\frac{3}{4}$ of a mile north of east of Porth Clais near the southern margin of the granite belt. The Cambrian sandstones here make a coast line about $\frac{1}{3}$ mile in breadth, but broad enough, however, to include generally the headlands and the "bights" of the numerous bays which indent it. The rocks which are scattered over the surface near the Nun's Chapel are, to a large extent, material from the coast which has been carried here. Some of them are sufficiently curious to merit attention, amongst which may be enumerated small fragments of chert, hard green sandstones of highly altered appearance, and gray argillaceous hydromica schists baked to an almost vitreous condition.

Among the natural consequences of the excessive sea action to which the St. Bride's Bay and St. David's Head coast are exposed, may be mentioned the destruction of the heavy dam constructed near Porth Clais, and the moulding into a thousand fantastic shapes of the cliffs and their débris? As to the first-mentioned phenomenon, a wall of heavy slabs has been knocked to pieces as if built out of cards, and that, too, while the mouth of the river is directed, not towards the open Atlantic, but to the other side of the bay. Remarkable natural arches and caves are found all along the coast line, and the storm beach referred to early in this paper near Newgale bridge is as perfect a wall as if the pebbles (which are, to a large extent, round discs) had been laid down in courses.

This rampart wall lies on a flat beach, above which it reaches a very uniform height of about 4 feet, with a broad base and narrow edge. Besides, these are beautifully moulded pebbles. Some containing several differently colored layers of siliceous material are ground to the most fantastic shapes.

The following may be given as a rough résumé of the impressions made upon the writer by the study of this very interesting region.

1. There is a striking analogy between some of the beds which constitute the Lower Cambrian in South Wales, and some of the beds which constitute the horizons proximate (both above and below) to the Primal of Rogers, or the Potsdam of the New York geologists. These analogics are not confined to kinds of rocks, but embrace paragenesis, topography, and accessory mineral contents.

2. There is a striking analogy between the orthofelsites, ash beds, syenitic granites and diabases, and the same rocks which in

the Appalachian region of America seem to be *older* than the Primal.

Some geologists have thought that the entire coast line which forms the subject of these notes is minced up by faults of different extents and directions. The writer was not able to convince himself of the existence of all of these faults; nor has he ever seen so many together. But on the basis of the experience gained in his short visit he does not wish to be understood as discussing the question of structure here at all. Still he cannot accept, as proved, the view of so many faults.

He believes the study of the structure in South Wales to be especially important to American geologists. The contact given in the sketch certainly seems to support a view of the age of the Cambrian in South Wales which the author has always combated, and still combats, as inapplicable to the Eastern United States. If, however, there were a network of faults such as has been stated the attempts to present a theory of superposition would be attended with the greatest difficulties; and, with no more investigation than he has had opportunity to make, would be entirely fruitless.

The following analyses, made in the laboratory of the writer by his assistant Mr. C. Hanford Henderson, are arranged to show the chemical constitution of the orthofelsites of Wales and of the Eastern Appalachians and that of the granitoid rock of St. David's. The numbers at the head of the columns correspond with those in the catalogue of specimens at the end of the paper. A represents a typical specimen of orthofelsite obtained from the copper belt of the South Mountain in Adams County, three miles W. by N. of the town of Fairfield. Its general color is dark-pink, and it holds light-brown crystals of feldspar. It is compact, but shows a tendency to scale on the surfaces which have been exposed to the weather. B is an analysis, by Dr. T. Sterry Hunt, of one of the Grenville porphyries, considered at the time it was made, viz., for the Canada Geological Survey Report for 1858 (pp. 188–9), under the head of the "Grenville intrusive rocks." This rock is described as an intimate mixture of orthoclase and quartz colored by oxide of iron. Throughout this paste, which is homogeneous and conchoidal in fracture, are disseminated well-defined crystals of rose-red feldspar apparently orthoclase, and—although less frequently—small grains of translucent colorless quartz; hardness nearly equal to quartz, sp. gr. 2.62.

The composition of the paste, as free as possible from crystals of feldspar and grains of quartz, is given under B.

	7.	8.	14.	A.	B.	15.	19.	21.
Ignition, ...	1.46	0.28	0.60	0.40	0.60	0.82	1.38	. . .
SiO_2, ...	58.98	95.51	73.41	73.62	72.20	76.90	75.48	76.54
Al_2O_3, ...	18.09	0.57	14.29	12.22	12.50	11.60	9.60	
Fe_2O_3, ...	6.54	. . .	1.11	2.08	. . .	0.71	1.73	15.38*
FeO, ...	. . .	1.86	1.14	4.03	3.70	2.56	4.26	
CaO, ...	7.50	0.15	2.28	0.34	.90	0.85	0.98	1.00
MgO, ...	2.02	0.32	0.94	0.26	. . .	0.59	1.32	1.34
K_2O, ...	0.43	0.16	1.57	2.57	3.88	0.73	0.56	0.57
Na_2O, ...	4.25	1.80	5.26	3.57	5.30	5.62	5.09	5.17
	99.27	100.65	100.60	99.09	99.08	100.38	100.40	100.00

A glance at the above analyses will show how closely related in chemical composition are the belt which has been held to be eruptive granite and Dimetian gneiss (15 and 19), and the so-called ash and tuffs (14), which border the belt. In the absence of conclusive demonstration of bedding in the former, its chemical constitution as well as its mineralogical structure entitle it to be classed in the granite group.

The rock marked in the catalogue of specimens as ash and tufa greatly resembles the normal orthofelsites in composition, as may be seen by comparing analysis No. 14 with A and B.

The orthofelsites from the two hemispheres do not resemble each other closely. No. 8 contains a great excess, and No. 7 a deficiency of free silica or quartz. But the great deficiency of alumina is its most striking characteristic. No. 7 is abnormal in its small percentage of silica and its large percentage of alumina and lime, indicating the presence of a lime plagioclase, probably andesite.

EXAMINATION UNDER THE MICROSCOPE OF SOME SPECIMENS OF THE ABOVE COLLECTION.

A.—A specimen of typical orthofelsite, from the South Mountain, Adams County, Hamilton Township, Pennsylvania, was prepared and examined for comparison with the above.

* By loss.

Under one Nicol it exhibited a fine granular paste, with some large crystal fragments of oligoclase and mica, the latter in strings through the mass. Exceedingly small prisms of a green mineral not certainly determined, abound. These specimens are of much finer grain than the Welsh orthofelsites. One of the slides exhibited broad flakes of microline and nests and groups of small mica and quartz fragments.

No. 7.—At 104 diameters the base appeared to be a pasty mass, containing large slate-colored patches of irregular outline, minute brown spots and lines due to hydroxidized iron. Both long and small wine-yellow crystals, sometimes with and sometimes without spots of iron oxide.

In one of the slides there were two instances of the occurrence of these groups of crystals somewhat imitating twin structure, but the angles between the main axes of the crystals in the groups were different. In most cases the sections were approximately parallel to the clinopinacoid, but one very large crystal was represented by the basal plane showing truncation by the clinopinacoid. With one Nicol most of these sections show feeble dichroism. At 240 diameters there was nothing of importance to add. At 800 diameters semblances of flow structure were visible in places. With crossed Nicols these large crystals behave like portions of pyroxene crystals. The rock mass seems to be composite and to have suffered a great degree of alteration.

No. 8.—General color of slides brown, owing to great number of large and small chestnut-brown masses distributed through the sections. A dark powdery substance is strewn over all, and numerous minute, short needles occur in small groups. In one place two small masses of radial dark-brown, hair-like crystals occur. Streaks of small fragments of feldspar, mica, (?) and quartz occur throughout the paste. The larger feldspar crystals are oligoclase, and these are more disposed in bands. The quartz grains are grouped in clusters through the silicic paste.

No. 14.—The appearance of the slides is of smooth white sur faces, alternating with darker rough surfaces, and speckled with fine spots of brown; apatite crystals are not infrequent. In one slide a dark-brown section of an amphoterolite lies on its clinopinacoid plane, but is opaque. Between crossed Nicols fragments of quartz, oligoclase, orthoclase, labradorite, hexagonal mica, and apatite appear. Some very much decomposed skeletons of a mineral, resembling hornblende in habit, and usually surrounded by iron oxide

stains, are visible, but if originally hornblende they are too much altered to retain many of the distinguishing characteristics of this mineral.

No. 15.—With one prism the slides show light transparent slices of minerals, crowded for the most part with striæ, and clothed with larger or smaller green fragments, showing hornblende cleavage and fully dichroic. Between the crossed prisms quartz, mica, and both orthoclase and plagioclase feldspar appear, the latter predominating, and oligoclase forming its chief constituent. The mica is least in amount.

No. 19.—The slides show light-colored masses with green and brown irregular patches.* With one Nicol the surface is dotted with occasional fragments of hornblende showing dichroism. In a plane of clinodiagonal main section the habit of the hornblende is seen. Small grains of quartz occur in groups and bands, generally rounded and not anywhere showing a trace of cleavage. A relatively large amount of feldspar is present, of which the greater quantity seems to be orthoclase. Some clinoclastic feldspar approaches 90° closely in the angle between the main and orthodiagonal axes. Both microcline and oligoclase are represented in the specimen. Besides these both mica and apatite are found, though more sparsely, and several slabs of labradorite are visible.

No. 21.—An exceedingly composite fine-grained mass containing very minute fragments of a great many minerals, and showing the most evident signs of great alteration. The ground mass is yellowish and chloritic, and on it grains of magnetite are freely shown. Labradorite, pyroxene and mica fragments also abound, together with quartz granules. It appears to have been originally formed of the waste of a chlorite schist by sedimentation, and to have been greatly changed subsequently, both by decomposition and new recomposition, and by the introduction of silica in solutions.

Dr. M. E. Wadsworth of Cambridge, Mass., has most kindly consented to examine the above slides, and has written the following description of them covering the principal points in question. It will be observed that he differs in many points widely from the writer's views of the origin of Nos. 7, 8 and 14, and he goes farther than I feel justified in doing in maintaining the non-sedimentary

* On looking at them without the Nicols, a little out of focus, a gridiron structure is apparent, which is however due to the accident of grinding the specimen. It might easily prove deceptive if the object were a section of a single mineral.

character of Nos. 15 and 19. In the recognition of the constituents of the various rocks, I am glad to find that we substantially agree, for I should have felt unwilling, without a further and more careful examination, to go on record in opposition to so eminent an authority.

"7. ANDESITE, VAR. PORPHYRITE. A grayish-brown groundmass holding porphyritically inclosed altered pyroxene and feldspar crystals, magnetite, and brown spots of some alteration product. The pyroxene is now replaced by a greenish-yellow, feebly dichroic, chloritic product, showing feeble aggregate and fibrous polarization. While some of the feldspar crystals show traces of a triclinic structure, they have been, on the whole, largely replaced by kaolin and other secondary products. The groundmass is greatly changed, but still presents characters indicating that it was once composed of feldspar, pyroxene, magnetite, and a felty base. While the structure and relations of the original minerals are in part preserved, the groundmass at present is composed of pyroxenic, feldspathic, ferruginous, quartzose, and fibrous granular materials, which, for the most part, are of secondary origin. The porphyritic relations of the larger crystals to the groundmass, the structure of the latter, and other characters of the section, point to a rock which was once identical with the Tertiary andesites, but whose present structure and mineral composition are largely owing to various secondary changes. In this condition it belongs to the class of rocks known as porphyrites, while its chemical analysis also indicates its andesitic character.

"8. QUARTZ PORPHYRY. This rock has suffered extreme alteration, but retains in some portions of its mass a structure indicating that it belongs to the quartz porphyries. It is now composed principally of a granular aggregate of secondary quartz with some feldspar. The forms of the original feldspars can be distinctly seen in portions of the sections, but they are replaced by the same granular aggregate as the other portions of the rock. The quartz oftentimes forms irregular concretionary masses, which are clear, although much of the section is stained yellow. Little aggregations and single microlites of rutile occur. The appearance and structure of the rock, coupled with its chemical analysis, indicate that it has had its bases largely removed by the percolating waters and replaced by silica.

"14. FELSITE, VAR. PORODITE. This is a clastic rock, composed of felsite (rhyolite) fragments. These fragments appear to have originally been the same as those ordinarily seen in a rhyolitic ash of the lithoidal and liparite varieties of feldspar, quartz, iron ores, and fine

ashes. These have all been subjected to more or less alteration, the glass devitrified, and much secondary quartz, mica, chlorite, kaolin, oxides of iron, etc., resulted; yet the original structure in most parts remains intact, and the original components can be readily recognized by any one familiar with the unaltered and altered state of volcanic ashes. It is possible that some of the fragments may belong to the more basic lavas,—a common occurrence in modern rhyolitic ashes. The rock can be denominated an old rhyolitic, felsitic, or quartz porphyry ash, according to the taste of the observer. I have called it a porodite, a name under which, in 1879, I grouped all the old fragmental rocks answering to the modern volcanic tufas. In my opinion this rock is distinctively a volcanic ash, and not formed from detritus, derived from the wearing down of pre-existing rhyolites or felsites.

"15. GRANITE. A fine-grained granite (hornblendic), much altered, and composed chiefly of irregular masses of orthoclase, plagioclase, quartz, hornblende, chlorite, a little mica, magnetic iron, 'leucoxene,' etc. The hornblende, chlorite, mica, and part of the quartz are plainly alteration products.

"19. GRANITE. A somewhat porphyritic fine-grained granite (hornblendic), composed of plagioclase and orthoclase, inclosing irregular masses of quartz, secondary hornblende, chlorite, magnetic iron, and 'leucoxene.' The feldspar is considerably altered, and contains microlites and other secondary products. The quartz is also partly an alteration product, and the section further contains some apatite, hematite, titanite, etc. This rock can be regarded either as a fine-grained granite, or a more coarsely crystallized portion of a quartz or granite porphyry.

"21. SCHIST. This is a schist formed from detritus, composed principally of quartz and fine mud. This, like the other rocks described, has undergone change, or is metamorphic. At present the rock is composed of the original quartz grains and magnetite, with some secondary quartz, feldspar, epidote, aggregations of mica and chlorite, tourmaline, ferruginous products, etc. The cementing mud is now largely altered to granular and fibrous materials, principally ferruginous, chloritic, and micaceous. Some of the observed feldspar is triclinic. This rock is distinctly clastic and sedimentary.

"*A*. RHYOLITE, VAR. FELSITE. This is an old rhyolite or felsite, showing a well-marked fluidal structure. Its brownish groundmass includes porphyritic crystals of orthoclase and plagioclase, and crystals and irregular masses of magnetite, hematite, and ferrite. The groundmass is believed to have been formerly the same as that of the modern

liparite variety of rhyolite, but it is now devitrified and altered to an aggregate of fine granules of quartz and feldspar, containing numerous fibres, granules, globules, and microlites, many of which are ferruginous. The feldspar is much altered, and secondary quartz in nests and veins occurs in it and in the groundmass. This felsite is the same as much of that in Eastern Massachusetts, which has been conclusively proved by Mr. Diller and myself to be eruptive, and associated with volcanic ash of the same material.

"This rock would ordinarily be called an old rhyolite, felsite, or feldspar porphyry.

"Of the sections above described, Nos. 7, 8, 15, 19, and *A* are regarded as distinctly non-fragmental, metamorphosed eruptive rocks; No. 14 as an eruptive (volcanic) ash now altered, and No. 21 as a true sedimentary rock likewise metamorphosed, of which Nos. 8, 14 and A, are apparently varieties of the same rock species—rhyolite—but 8 is so much altered that a definite statement regarding it cannot be made."

Views of Orthofelsites.

The change and the diversity of opinion concerning these rocks can be well studied in the *Reports of the Canada Geological Survey*, from 1858 to the present time. Dr. Hunt's investigations in the former year have been mentioned as well as the classification of the rocks under "eruptive." This is repeated in the report for 1863, p. 654. In the report for 1871–2, Mr. Walter McOuat reports on Lake Mistassimi "a feldspathic rock of brecciated character and calcareous seams, showing dull green steatitic mineral." Its horizon is between the gneiss and the limestone, and corresponds to Richardson's second group which includes the copper-bearing rocks.

In 1875–6, in *Dawson's Explorations of British Columbia* (p. 153) the porphyritic group is spoken of as "volcanic rocks," though in another place they are said to contain traces of vegetable fossils, and some are thought to have been a feldspathic paste. On pages 350–1 E. F. Matthew and R. W. Ells describe the quartziferous porphyries of the Coldbrook group. Of these, angular portions project into the Upper Silurian slates, showing that at the period of the deposition of the latter the felsite must have had an irregular form. On pp. 371–2, etc., Mr. Hugh Fletcher describes the Coxheath felsites as composed of compact and granular feldspar. On page 381 he maintains the pre-Silurian age and the stratified character of these felsites: "1st. Because of their lithological resemblances to Lauren-

tian elsewhere. 2d. Because of the pebbles of felsite in the George River limestone and the lower Silurian coarse conglomerate. 3d. The rocks are unquestionably bedded. 4th. The lower Silurian shales lie on them without a trace of alteration. 5th. No intermixture of the lower Silurian slates and feldspar takes place at their contacts. 6th. Flexures of strata in Cape Breton are in the continuation of the folds of the Appalachians, which bring the Huronian and Laurentian up in Newfoundland and New Brunswick, and may be expected to do it in Nova Scotia."

In the *Canada Geological Survey Report* of 1877–8, Mr. Bailey (DD, p. 4) considers the felsites, like those of North Wales and Cumberland, "*igneous.*" Report F., p. 4, of the same volume, Mr. Hugh Fletcher describes, according to his views, the Mira and Coastal felsites.

In the report for 1878–9, Messrs. Bailey, Matthew and Ells consider their Division 2 formed of syenite, gneiss, quartzite, felsite and limestone. Division —, gray and black petrosilex, largely made up of volcanic and semi-volcanic materials. In the report for 1879–80, "D," Mr. R. W. Ells speaks of "felsite dikes."

List of Specimens from South Wales (and elsewhere) Submitted with this Paper.

No. 1.—Plug of dolerite, thought to be of Miocene age, intersecting the carboniferous trap. Carlton Hills, Edinburgh.

No. 2.—Trap, interbedded with carboniferous sandstones, forming, with them, the main mass of the hill on which is poised "Arthur's Seat." Edinburgh.

No. 3.—Carboniferous trap. The same.

No. 4.—Plug of newer dolerite, burst through volcanic agglomerate which forms the highest peak, or Arthur's Seat. The same.

No. 5.—Felsite, from boulder. Inversnaid, Scotland.

No. 6.—Llandeilo flags, from two hundred yards northwest of Roch's Castle. Pembrokeshire, South Wales.

No. 7.—Felsite porphyry, just southeast of the base of Roch's Castle. The same.

No. 8.—Orthofelsite porphyry. The same.

No. 9.—Pebble of interbedded quartz and green siliceous rock. St. David's, Pembrokeshire.

No. 10. Yellowish-green hydromica schist. St. John's Point, Rhosson, Pembrokeshire.

No. 11.—Porphyritic ash, imbedding orthofelsite porphyry.
Near St. David's, Pembrokeshire.

No. 12.—Quartzite, with epidote. Trelethyn, Pembrokeshire.

No. 13.—Hällaflinta. Penman, Pembrokeshire.

No. 14.—Crystalline beds of ash and tufa, containing fragments of orthofelsite. St. David's, Pembrokeshire.

No. 15.—Amphibole granite (or heavy-bedded gneiss?).
St. David's, Pembrokeshire.

No. 16.—Characteristic ice-moulding in boulder clay.
Near St. David's, Pembrokeshire.

No. 17. Altered green shale and sandstone.
Nun's Chapel, near St. David's, Pembrokeshire.

No. 18.—Cambrian red sandstone.
Porth Clais, one mile and a half south-west of St. David's, Pembrokeshire.

No. 19.—Amphibole granite (or heavy-bedded gneiss?).
Porth Clais, Pembrokeshire.

No. 20.—Vein of trap, through Cambrian beds.
Porth Clais, one mile and a half south-west of St. David's, Pembrokeshire.

No. 21.—Cambrian siliceous schist, called "Altered Cambrian" by some geologists.
From lower mill. Porth Clais, Pembrokeshire.

No. 23.—Orthofelsite and orthofelsite porphyry.
One hundred feet west of Clegyr Foig, Pembrokeshire.

No. 24.—Band of re-made rock, including orthofelsite.
Edge and foot of knoll, Clegyr Foig, Pembrokeshire.

No. 25.—Porphyritic lava. Back of Clegyr Foig, Pembrokeshire.

Labors of Hicks and others in Pembrokeshire.

A memoir on the rocks of the region referred to above would be incomplete without at least a short summary of the results obtained by Dr. Hicks. The steps by which Dr. Hicks reached his conclusions are detailed in the *Quarterly Journal of the Geological Society of London*, volumes xxx., xxxiv., and xxxv.

From them it appears that while making a section near St. David's, in 1864, with Mr. Salter, they first noticed that the great syenitic band which passes through that town was, in part, stratified. He first thought it was altered Cambrian, but the syenite did not appear to penetrate any of the beds, and therefore the alteration could not be due to it. Again, they noticed that the rocks forming the Cambrian conglomerate were made up of fragments of rock resembling that of this ridge. Their first hypothesis was, that here was a Cambrian island, with a nucleus of syenite, which was communicated to the British Association, in 1864, by Mr. Salter.

In 1866, Dr. Hicks concluded that the central portion of the ridge was also, for

the most part, not "volcanic," but "altered sedimentary." In 1871, Messrs. Harkness and Hicks made a communication to the Geological Society showing that these rocks were not only of pre-Cambrian age, but of sedimentary origin. 1. The bedding of the central part of this ridge strikes, invariably, northwest and southeast, and hence is discordant with the upper (marginal) portions, where the strike is northeast and southwest. 2. The chemical composition of the rock proves that it is not a true syenite. With it were associated hard greenish-colored ashy shales, considerably altered in character.

In the years 1874 and 1875 much further work was done. The strike being northwest and southeast, Hicks regards the rocks at Porth Lisky as higher than those in the middle part of the belt. These lower rocks he named Dimetian, and while the trend of the ridge in which they were exposed was northeast and southwest, he believes the strike of the rocks to be transverse to this.

The narrow, uneven margin of the ridge he believes to be the superior or Pebidian series, of which the strike was *with* the trend of the ridge, and thus transverse to that of the Dimetian. He considered its structural discordance with the overlying Cambrian series proved by the difference of the strength of the dip only. The greenstones parallel with Ramsay's Sound he thought principally made up of these rocks, with some intrusive dikes, and he imagined that the Dimetian and Pebidian were analogous to the Laurentian.*

In 1877 he had established the constituent beds of the Dimetian as follows: 1st. Quartz porphyries (which were positively intrusive, and probably of volcanic origin). 2d. Fine-grained quartz feldspars, interbedded with the above. 3d. Ashy, shale-like rocks, of dark-green or blue color, sometimes highly-indurated, altered basaltic. 4th. Compact granitoid rocks interstratified (sic) with quartz breccias. 5th. Quartz breccias. 6th. Quartz schists, granitoid (sic). 7th. Quartzites, usually slightly green. 8th. Purplish and greenish chloritic bands, with schistose or rude cleavage-structure. 9th. Crystalline limestone beds. Series 4, 5, 6, and 7 make up most of the Dimetian beds, and collectively show a thickness of 15,000 feet.

Professor Bonney believed 4, 5, and 6 to be altered. Messrs. Judd and Davies thought the laminated beds were of the same material as the dikes. The Pebidian series consisted of: 1st. A sea-green felsitic matrix, containing spherulitic felsitic lava, angular green shale, chlorite schist, and quartz. 2d. *Con*glomerate of the same material as 1, which is an *ag*glomerate. 3d. Light-green, thin, banded shales, which are porcelain-like. 4th. Mostly hidden by Cambrian overlaps and faults. 5th. Alternations of silvery-white schists, purple shales, and light-green clay slates. 6th. Greenish, reddish, and purplish indurated ashes and shales. 7th. (At Clegyr-Foig) red, yellow, and white sands and slates, alternating with beds of tuff. 8th. Conglomerate and ashy beds. 9th. Thick band of felstone, weathering white. 10th. Hard, bright-green ash bands, in which epidote is found. 11th. Reddish and purplish ashy schists.

The Cambrian beds seem at first to be conformable, but on closer inspection of them are observed to wave over the Pebidian, and form contact with different rocks; and also to dip at a lower angle. The mass of the Pebidian he concludes to be volcanic, and to have been subjected first to subaerial and later to submarine action.

The lowest agglomerate was formed near the subaerial volcano. There is a strong general resemblance between these rocks and the igneous rocks of the lower Silurian.†

* Quarterly Journal of the Geological Society of London, vol. xxx., p. 229.

† Ibid., vol. xxxiv., p. 153.

In 1879, Dr. Hicks made a closer investigation of Roch's Castle, and conceived that he had then discovered a new series of beds which were younger than his Dimetian, but older than the Pebidian, which he named "Arvonian."

His column of pre-Cambrian rocks is represented as follows:

Pebidian.	(*a*) Micaceous talc, and chloritic schists, with slate and massive green bands containing epidote, serpentine, etc.
	(*b*) Tuffs, indurated ashy shales, breccias, silvery-schists, porcelainites, conglomerates, and agglomerates.
Arvonian.	Breccias, hällaflinta, and quartz felsites.
Dimetian.	Quartz rocks, granitic gneiss, and compact granitoid rocks, with bands of crystalline limestone.

In the discussion which followed the presentation of these views to the Geological Society (February 5th, 1879), Professor Hughes challenged the grounds of Dr. Hicks's differentiation of the beds, and spoke of the three series as the "granitoid" (Dimetian), the felsitic (Arvonian), and the volcanic (Pebidian).*

In 1879 Dr. T. Sterry Hunt, read before the American Association for the Advancement of Science at its Saratoga meeting, September 1st, 1879, a paper on the "History of some pre-Cambrian Rocks in America and Europe," which was divided into, 1st, an introduction, giving a short sketch of the creeds of the two schools of geologists, which are now at variance on the question of the origin and age of the crystalline rocks; schools which might be designated the Plutonists and the Metamorphists, both of which in Dr. Hunt's opinion have retarded the logical development of crystalline geology. The second part deals with the pre-Cambrian rocks of America, and gives the growth of opinion regarding them from that of Maclure in 1817 to the present time. The third part takes up the pre-Cambrian rocks of Great Britain, including those of North Wales and Anglesey as well as South Wales. His conclusions identify the Pebidian with the American Huronian, the Arvonian with the lower Huronian and Swedish hälleflinta groups,† and the Dimetian with the Laurentian, proper (*i. e.*, the Ottawa and Grenville divisions in Canada), and not as, he believes, Dr. Hicks was mistaken in thinking, the *Upper* Laurentian.

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* Ibid., vol. xxxv., p. 285.

† Dr. Hunt, in 1880, gave reasons for believing that the great Petrosilex series, which he had formerly described as occupying a position at the base of the Huronian, and which he identifies with the Arvonian of Hicks in Wales, is really a distinct series separated by a stratigraphical break from the base of the Huronian. He argued this from the absence, in many regions, of the Arvonian between the Laurentian and the Huronian, and noted the fact also, that Bailey in New Brunswick had detected such a stratigraphical break, and the presence of Arvonian conglomerates in the base of the Huronian.

SOME NOTES ON BLAST FURNACE PRACTICE.

BY CASIMIR CONSTABLE, C.E., NEW YORK.

DURING the years 1875 to 1879 I had charge of the Rockwood furnaces and mines, situated forty miles from the nearest railway communication at that time, and one hundred miles north of Chattanooga, Tenn., by the Tennessee River. The small furnace with old-fashioned stoves, then in blast, was built under great difficulties by General Wilder.

The early conditions were somewhat as follows: The ore was fossil ore of the Clinton group; very fine and generally wet, without other admixture. The coke had a large amount of ash, and the furnace appeared to be badly scaffolded at times. On many days only a few tons of iron could be obtained. The founder generally increased the revolutions of the engine when signs of chilling appeared. The cinder at such times was black, very scoriatious, often closely resembling mill cinder. When the pressure was increased (the joints being the old-fashioned rust joints), leaks in the blast-pipe occurred. It was noted that when the blast was stopped, and the leak but imperfectly remedied, the furnace improved a little. This set me thinking on the right track; and I took the responsibility of becoming my own founder for a time. A scaffolded condition had existed, and the situation was a trying one. Strange to say the negroes proved excellent furnace-men.

Conceiving the hearth of the furnace to be similar to the grate area of a steam-boiler, capable of disposing of but so much fuel per hour, and requiring only a corresponding amount of air, it follows that an excess of air will burn the fuel not yet arrived at the hearth, and raise the melting-point far above the tuyeres. This might produce scaffolding or at any rate choke the boshes, and leave less fuel to be consumed in the hearth. Thus for the time being less air would be needed, as the continued burning of fuel in and above the boshes, would only aggravate the trouble. This condition of affairs accounted for the black cinder; the heat above having melted ore not yet perfectly reduced.

This view decided me to reduce the revolutions of the engine; the furnace finally became gray, as might have been expected. Any attempt to increase the speed produced black cinder and hard iron;

nor would a reduction in burden improve the matter. The furnace responded very quickly to a change in the revolutions of the engine, if made soon enough. It proved abnormally sensitive, which accounted for the founder's difficulty in running it.

The changes which occurred constantly in the cinder were found to correspond with the changes in the speed of the engine. They were so striking in this furnace that it soon became possible to grade them. A change in the cinder proved to be the earliest indication that the furnace was about to become more gray or the reverse, which the foreman could then anticipate by a change in revolutions.

An inexperienced foreman soon became very expert in determining a change. Six grades of cinder were recognized, corresponding, when normal, with six grades of iron,—Nos. 1 and 2, foundry, 3 and 4, mill, mottled, and white.

Samples of every flush were placed side by side by the cinder-men, the casting flush being marked by a small piece placed on top of it. These samples were large enough to show the top surface and section; their color and appearance being the means by which one judged them. An inspection of these in the morning was one of the best reports of the manner in which the furnace had been running during the night.

No. 1 cinder had a bright greenish white top, and a solid gray fracture.

No. 2 had a brownish white top and a more polished blue-gray section, rather darker than No. 1 and the top never green.

No. 3 was covered with quite a brownish froth, was olive green in section with some vitrification near the surface. Later on, the color in section was *brownish blue* in a different furnace, but with the same ores.

No. 4 was darker on top, and sparkled as it ran from the furnace. In section it was like No. 5 in the upper portion and No. 3 in the lower, next the ground; that is, blackish and full of blow-holes on top.

No. 5 brownish black to black on top, more or less full of blow-holes, and pitted. In section blue black, and if abnormal, full of blow-holes.

No. 6 was even blacker, with rougher top, ran more sluggishly, was black and more full of holes. In section it nearly approached a mill cinder, which might be represented by No. 7.

I do not describe them as fully as might be, because each furnace cinder will have its own peculiarities. Thus No. 1 and No. 2 fur-

naces on the same ore and fuel produced very different slags. The object was to run on a No. 1 or a No. 2 cinder. With practice the foreman became very expert in determining these grades.

The manner of running out, the general outline of the stream as it flowed, the color and appearance of the top, in particular when cool, and finally the section, if necessary, were the points observed to determine these grades.

If the object is to run on mill iron, a dark cinder, the result of a heavy burden, may be a normal cinder, and a furnace may be kept steady on it. At Denain, France, they were running thus steadily in 1880, but the cinder was what I would call a normal one, that is, though black on top and with dark section, it was *free from blow-holes,* and when a thread of it was held to the light it was transparent and not black and opaque; hence not too high in iron.

The cinders I have described are abnormal ones, indicating, in the furnaces described, a rapid change from bad to worse, and vice versa. The foreman always tried the quality and color of the "thread" by drawing out the slag on the point of a rod. If it had been black and opaque, the first translucence indicated a change for the better towards Nos. 1 and 2. The threads of Nos. 1 and 2 were transparent and white; 3 was colored, and 4 black and opaque. The length of the thread was also noted. The appearance of blow-holes always indicated that the revolutions were excessive.

The writer was interested to note that on the Continent, where cinder is often observed as a test, notably by Pernot in his steel practice, that there too a spongy cinder was abnormal, and indicated that the operation had gone too far. The analogy may not be unreasonable, since I think it shows excess of oxygen in both cases.

During the first few months, I found great assistance in plotting on small leaves of profile paper containing twenty-four vertical lines, representing the twenty-four hours of the day, the relative temperature of blast, the grade of cinder, and the corresponding changes of the engine. It was made into a block one inch and three-fourths of an inch by six, and could be carried in the pocket, and the plotting made from hour to hour. Later on with greater expertness and greater steadiness this became unnecessary.

The three principal variables affecting the furnace are the *scales,* the *temperature* of blast, and the *revolutions* of the engine. The writer eventually took the former under his own special charge, thus eliminating it, as it were, from the problem of the foreman. As the stoves were but imperfect cast-iron ones, incapable of quickly in-

creasing the temperature, the duty of the founder was to maintain his temperature as evenly as possible. The revolutions of the engine, then, alone remained as a single variable which, by careful attention to all the symptoms, could be intelligently changed.

Pyrometers, even admitting their inaccuracy, became of great assistance in this way. A rise of temperature, even of a few degrees, added to other symptoms, at certain times allowed one to anticipate a return to a gray cinder, and permitted an increase of revolutions in advance, thus gaining a little in output. But if, on the contrary, the revolutions were increased unadvisedly, the furnace ran on to dark, abnormal cinder, with always a reduction in yield as well as in grade. For this reason it was advantageous to push the revolutions, if only for two hours, when a chance offered, but to draw back at the first indication of change in the wrong direction. This prevented "black turns," with scouring cinder, hard tap-hole, dark tuyeres and possible loss of tuyeres, and all the troubles attending a scaffold.

In the event of not reducing the revolutions in time, it was seldom possible to get aid from increased temperature of the blast, since at such times it always fell, and the difficulty was to maintain it at the steady normal temperature. A careful watch was kept on the outflow of gas from the chimney, since a weakening in its appearance was apparent before the temperature of the blast began to decrease. If, in addition to this, the cinder showed a change toward a higher grade (from a No. 3 to No. 4, for instance), the revolutions were lowered, and the stoves watched to prevent, if possible, a reduction of the temperature. On the other hand, the first improvement noticeable in the cinder (the temperature not being far from normal) was the indication to increase the revolutions as far as seemed possible.

In this way the furnace continued to run on for two years and a half more, with a daily product seldom differing much from the average of the year, and with the loss of but a few tuyeres,—a practical sign that a furnace has been pretty free from trouble. So sensitive was this furnace that it was necessary to have the foreman sleep at the furnace in order to determine in time when a change in speed of engine was required. Otherwise by morning the furnace might be on mottled, and even white iron, with a black cinder heavy with iron. Naturally the yield of the furnace would remain below the average for several days, as a consequence of a few hours' unwise driving.

The foreman being taught only to trouble himself with varying

the revolutions of the engine; and to keep, under ordinary circumstances, the temperature steady, watched only the gas, the grade of cinder, and the pressure of blast (though this last was found to be an uncertain and tardy indicator at these furnaces, compared with the cinder test).

The founder had enough to look after, but not too much. He was advised, but not interfered with. The result was, in time, that, instead of referring a "black turn" in the furnace to wet stock, or any other excuse, his own experience told him that he had not noted the indications of change quickly enough, or that he had attempted to drive the furnace too hard.

I believe I was among the first to run a furnace mainly by varying the revolutions of the engine. I am indebted to Mr. John Griffen, of Phœnixville, who, as far back as 1869, called my attention to the fact that the yield of furnaces was proportional, in the long run, to the amount of air blown. He it was who suggested that the revolutions, and not the pressure, should govern the running of the furnace. At that time (1869), however, I could find no furnace working by this method; old furnace-men generally regarded the pressure as a better index.

Now that we have improved hot-blast stoves, furnaces work much more regularly, and, moreover, the temperature can be made a much more important lever in controlling their working. Still I believe that, on whatever lever the main reliance is put, a study of the cinder will always be a most useful means in promptly determining a change; and that, at the first appearance of a scaffold, a reduction of revolutions, as well as an increase of temperature, where possible, will generally save much of the trouble incident to furnace-working.

By constantly watching the cinder, as well as by occasional analyses (the ore and fuel being from the same mines), I succeeded in judging, with some degree of accuracy, the amount of silica in a No. 2 normal cinder. This, when you have no laboratory, is worth attempting. A large-sized sample was always kept in connection with its analysis, so as to practice the eye to differences of appearance corresponding to different proportions of silica.

The practice of carrying more lime is now very general; for, owing to the higher heats of fire-brick stoves, a more infusible slag becomes necessary to prevent the reduction of silica and the formation of highly siliconized iron. In our case the iron was not silver-gray, but the analyses of pig showed considerable silicon, though

the cinder contained but 36 per cent. silica. This, in the presence of phosphorus, made the iron very weak.

The cause of the high percentage of silicon in the pig was laid finally to the large amount of alumina, often 26 per cent., which acted, as has been suggested, as an acid, and, of course, neutralized the lime.* I am aware that some metallurgists doubt this acid action on the part of alumina, except in some minerals. However, lime was added with this object in view, and this was increased until the cinder contained only 28 per cent. of silica. The result of this treatment on the strength of the iron was determined by a rudely contrived testing-machine on three samples cast every other day in the foundry. These were one inch square and twelve inches between supports, and were broken transversely. From 2400 lbs., breaking weight, we reached 3045 lbs., corresponding to 22,097 lbs. tensile strength. This high figure would, probably, not hold good for larger sections,—the skin of the small sections adding, of course, to the strength. The tensile strength of the sample was determined by Messrs. Rheilé Brothers.

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* Professor Jordan, of Paris, informed me, in 1879, that he generally regarded alumina as an acid when in excess in cinder. This point was arrived at practically when the alumina exceeded half the silica.

ERRATA.

VOL. XI. Page 191, foot note, for September read August.

VOL. VIII. Page 486, sixteenth line from top, for 10,000 read 5000.

VOL. IX. Page 17, nineteenth line from bottom, for hematites read magnetites.

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[AUTHORS' NAMES IN SMALL CAPS; TITLES OF PAPERS IN ITALICS.]

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